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Toward Soil Security

on the Northern Great Plains

U. S. DEPARTMENT of AGRICULTURE

FARMERS' BULLETIN NO. 1864

FOREWORD

This bulletin deals with soil and water conservation problems which relate to the agriculture of the northern Great Plains. The vast area is designated as Region 7 for administrative purposes and includes the States of Montana, Wyoming, North Dakota, South Dakota, and Nebraska.

Washington, D. C. Issued January 1941

TOWARD SOIL SECURITY

ON THE

NORTHERN GREAT PLAINS

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Soil Conservation Service, in Collaboration with Subject-Matter Specialists

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FIGURE 1.—Drought in the early and middle 1930's brought into sharp focus a situation on the Plains which had long been developing. This picture shows drifted soil in Tripp County, S. Dak.

Toward Soil Security on the Northern Great Plains

One-sixth of the U. S. A.

THE NORTHERN GREAT PLAINS, whose soil and water we are to consider here, lies within the boundaries of five States—Montana, North Dakota, South Dakota, Wyoming, and Nebraska. The combined area of these five States exceeds 470,000 square miles. It is larger than the combined area of Sweden, Norway, Greece, Ireland, and Scotland. As a crow flies, the distance from the northwestern corner of Montana to the Missouri River in southeastern Nebraska, is more than 1,200 miles. Continuing eastward from this point on the Missouri River for the same distance would bring one to a point approximately 50 miles out to sea off the New Jersey coast.

In general, the Great Plains of the United States are in the form of a huge inverted triangle with the broad base on the Canadian border. The apex of the triangle extends southward well toward the Gulf of Mexico. But the lowermost limits of the northern Plains may be considered here as the Kansas-Nebraska border line. The Rocky Mountain wall on the west defines the western boundary of the northern Plains with considerable precision. The eastern boundary is always vague. Some authorities place the boundary at the ninety-eighth meridian; others at the one-hundredth. Still others choose a rather indefinite belt where the rainfall averages about 20 inches annually.

During the drought years in the early and middle 1930's no region in the country suffered economic distress more severely than the northern Great Plains. The migration of farm families, the terrible duststorms of 1934 and again in 1936, foreclosures, delinquent taxes, mounting relief rolls—these grim memories need not here be stressed. But they are sharply remembered by those who still remain on the land and by those who have been forced to leave.

The dust that hid the sun brought out a cruel fact. The fact is that Plains farming practices have been, for the most part, out of harmony, and still are out of harmony, with the soil and climate. The drought during the 2 tragic years had only accentuated a situation which had long been developing. In many instances farming practices have injured the land. Some areas have become decreasingly productive even in good years (fig. 1). In the years of scant rainfall, the losses of both crops and forage have been severe. Furthermore, neither

reserves of feed, money, nor moisture could be stored against the hazards of another season.

The only permanent solution for the agriculture of the Plains is to use the land in ways that are compatible with the soil and weather. "It is necessary," says Dean H. L. Walster, of the North Dakota College of Agriculture, "that we cooperate with our environment here on the Plains and not work against nature."

But one can cooperate with nature only on her own terms. For nature is not to be conciliated by clever ideas which take into consideration only one or a part of her laws. Herein lies the risk in approaching the problems of the Plains. It is easy to dispose of some of the physical characteristics of the Plains by saying that it is a treeless region of erratic and limited rainfall, high winds, high evaporation, and wide variations in temperature and growing seasons. All this is true, but it is also true that there are extremely wide variations in the soil and crop adaptations. Nothing less than complete harmony in the interlocking relationship of soil, climate, and plant life will satisfy nature. Nature, in time, will deal rudely with any one panacea applied to correct situations so complex.

The next section will briefly touch upon some of the major characteristics of the climate, soil, and natural vegetation. The following section (p. 8) indicates some of the disastrous consequences of unwise settlement and some of the panaceas that were in vogue. Soil erosion is discussed briefly in the section beginning on page 14. The major portion of the bulletin, beginning on page 18, is devoted to a discussion of the controls and cures for land misuse. These suggested practices, in the main, represent the methods of control that are now being used in the several demonstration areas of the Soil Conservation Service. The use of these practices in a few specific demonstration areas is included in the section beginning on page 47. The last section (p. 76) points out a democratic procedure whereby landowners and operators may effect a more appropriate use of the land through soil conservation districts.

Weather, Soil, and Cover

IN THE NORTHERN PLAINS, as elsewhere in the Great Plains area, rainfall is light and extremely uncertain. Apart from the eastern half of Nebraska, the eastern portion of the Dakotas and a few other extremely isolated spots, the entire region receives something less than 20 inches of rainfall for an annual average. Once you leave the Red River in North Dakota and strike westward the average precipitation drops from about 20 to 15, and to as little as 12 inches in the western part of the Plains in Montana. Eastern Nebraska, in most years, receives about 28 or 29 inches of rainfall, but again as you travel westward the precipitation drops to about 14 inches, or even less, where the Plains floor edges into the foothills of the Rockies in Wyoming.

Agriculture on the Plains must survive on 20 inches of rain or less. Yet it is not the low average of precipitation that is the biggest handicap. The extreme variability between seasons and the extreme variability within months of a single season provide the basis for the most critical agricultural risks. Areas that are humid in one year are arid in others. While marked variations occur from year to year, the region is also plagued with irregular minor drought cycles of several years and major cycles of many years' duration.

All of these variations are now recorded at the numerous Weather Bureau stations throughout the Plains. Consequently, it is easy to tell what has happened, but it is not yet possible to tell what will happen from a long-range point of view. Until further progress is made in long-time weather forecasting there is no way of anticipating rainfall variations.

When rains return to the Plains some people are persuaded that never again will droughts be severe (fig. 2). In 1886 Lauren Dunlap, of the North Dakota State emigration office, said: "Never since the settlement of North Dakota began in earnest has drought been so general." And then he added: "* * * such an experience may not be repeated in the life of the youngest Dakotan." But Dakotans lived through severe droughts in 1893, 1897, 1900, 1910, 1917, 1934, and 1936.

FIGURE 2.—Faith and hope mount when rains bring crops. This picture, taken in 1939, shows barley being harvested with a combine.

Soils

East of the Missouri River in North and South Dakota and in most of northern Montana, the soils have developed from glacial till. And, as with glaciated soils elsewhere, they vary a great deal. On the remaining part of the Plains the soils were laid down by a number of forces. Some were derived from alluvial deposits along stream beds; some are the result of deposits formed under water in lake beds, and some are loessial deposits formed by the wind.

For the most part the soils in the eastern portion of the Plains are rich and deep and, "its thickness is so great," wrote C. F. Marbut, "that the world's experience up to the present time affords no basis for placing any estimate on the duration of the productivity of these lands." In the drier parts of the northern Plains, however, the soils are generally shallow, and if subjected to too intensive use they may be severely injured in a comparatively few years.

While the fertility of semiarid soils is their greatest asset this fact is frequently the cause of misuse. Bumper yields in years of ample rainfall have often led to unjustified expansion when yields that could be expected over a series of years were taken into consideration. Over and over again these good periods have led to disaster when they have been followed by successive years of low rainfall.

But apart from their general richness and the fact that these soils have been developed under a grass cover in a semiarid climate, in other respects the Plains soil varies widely. There is a wide range in water-absorbing and water-hold-

ing capacity. Those soils with fine-textured surfaces usually found in clays and clay loams, retain water exceedingly well once water is absorbed. However, the rate of absorption, in the absence of water-saving measures, is so slow that much water runs off or is lost through evaporation. But even if water-saving measures are provided there are years on the Plains when there is little water to save. In this event, these soils may be moved by the wind since the rainfall is insufficient to grow an adequate vegetal cover. Of course the most severe movement of soil occurs on cultivated land or denuded range land.

Sandy soils usually take a large percentage of the rainfall. The rain usually penetrates deeper in them than in the heavy or hard-land soils. However, it is difficult to raise big clods in sandy soils; and big clods, in the absence of vegetation, resist attacks by the wind.

There are still other variations in Plains soil which influence the amount of water that can be retained for the benefit of crops. At varying depths beneath the surface some areas are underlain with porous layers of gravel or coarse sand. Other areas are underlain with subsoil layers known as hardpans or clay pans. Of course the slope of the land has a marked effect on the amount of water that the soil can absorb.

In some instances the heavy clay soils in the northern Plains are as vulnerable to the wind as are the lighter textured soils. When these soils dry, the body is a loose mass of granulated particles. The thin clay crust cracks. The edges curl and break down readily. When winds come, the fine, lighter particles blow away. The heavier aggregates hug the ground and eventually pile up in dunes like sand.

Natural Vegetation

Variations in both climate and soil are chiefly responsible for the characteristic natural vegetation on the northern Plains. Before the coming of the white man, the vegetational scene was something like this:

East of the one-hundredth meridian the dominant plant association was made up of little bluestem, prairie junegrass, porcupine grass, and prairie dropseed. Mixed in with these were tall grasses. This higher vegetation, being more in evidence than the shorter grasses, suggested the designation of the tall-grass region. While these tall grasses could be seen over wide areas they were more in evidence along streams and draws. Big bluestem and switchgrass were among the taller grasses. Cordgrass and sedges were dominant in the wet bottom lands, while switchgrass and bluestem were most in evidence on adjoining areas of better drainage. Even though the Sand Hill region of Nebraska has a dry climate the sandy soil, due to moisture conditions, favors the growth of tall grass.

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West of the so-called tall-grass area and where the rainfall is normally below 18 inches, the vegetational scene was composed of both medium-length and short grasses. The chief medium-length grasses were western wheat and needle-and-thread, while the short grasses were chiefly blue grama and buffalo. Niggerwool was a part of the short-grass association but it is a dry-land sedge. Niggerwool was dominant along with grama grass in the more northern areas; buffalo grass dominated the more southern portions.

These grasses once occupied practically all of the land. But there were notable exceptions. Scattered throughout the northern Plains are spots of higher elevations, such as buttes and escarpments. On most of the elevations that rise above 4,000 feet it was the ponderoso pine that dominated the vegetational pattern, then as now (fig. 3).

Near the Rocky Mountain front there were two significant patterns of vegetation. One was dominated by vegetation that is typical of the midcontinental Rockies and the Great Basin. The other was influenced by the Palouse Prairie type of vegetation.

From the midcontinental Rockies and Great Basin the sagebrush and saltbush vegetation moved across and intermingled with the grasses of the Plains. In general this sagebrush and saltbush type extended over all of western and central Wyoming, south central and southeastern Montana, and northwestern South Dakota with the exception of the pine-covered high mountain areas.

The Palouse Prairie plant association was dominated by blue bunch fescue and spiked wheatgrass. During a favorable period this association of grasses migrated into central Montana. It can still be found there in isolated spots favorable to its perpetuation.

In general, this brief description of the natural vegetation in the northern Plains presents what might have been observed by early explorers of the region. Where extensive areas of sod have been turned under and ranges have been harmed by overuse or by blow dirt from surrounding areas, we now find the vegetation in such condition that its effectiveness in conserving soil and water is greatly reduced. The medium-length grasses, being more subject to injury by severe use, have lost their foothold, to the advantage of the shorter species which still make up the general flora of the country. Under continued severe use the short grasses begin to lose their foothold, and the annuals move in.

In general it may be said that the old climax types of vegetation held sway on the Plains until the flocks, herds, and plows of the white man upset the natural balance. With our plows, herds, and flocks we have abetted the enemies of the climax grasses. The enemies have marched in. Such annual weeds as Russian-thistle, mustard, and peppergrass have invaded most of the land that has been improperly managed. Perennial weeds have also profited by the overuse of the better range grasses. Most common among these are silver sage and snakeweed. In this ceaseless drama of nature we have a war among plants at our feet. It is

bloodless. It is noiseless. It is mass murder on a colossal scale. It is fought without guns, but it is war, nevertheless.

Other changes, apart from the appearance of weeds, are now very evident. In the more humid areas on the eastern border we find an increase in such unpalatable grasses as cordgrass, switchgrass, and sand reedgrass. Likewise, we find a decrease in such palatable grasses as bluestem, western wheat, and grama. Cordgrass and switchgrass have spread to areas that have been overused.

FIGURE 3.—Though grasses predominate as the natural vegetation on the northern Plains, exceptions are found on the buttes and escarpments, which grow ponderosa pine. This picture was taken near Sturgis, S. Dak.

Sand reedgrass has moved out onto overgrazed areas. About 40 percent of the vegetation of the Sand Hills is now composed of sand reedgrass. Perhaps even more significant is the tremendous migration of the dry plains grasses into the normally wetter areas to the east, due to the accumulated effects of severe use, augmented by the recent droughty years. These include needlegrass, western wheat, grama, buffalo, and others.

Changes in vegetation now taking place near the Rocky Mountain front may be less apparent than they are to the east, but they are no less significant. Overuse and drought are chiefly responsible for the eastward and northward migration of sage brush and saltbush over wide areas.

Trials, Errors, and Panaceas

"GOOD, FINE GRASSES grow evenly all over the country," reported Gen. Luther Bradley to the War Department in 1868. "Stock can range," he said, "and feed all winter and keep in excellent condition without artificial shelter or fodder." Bradley, being in command of cavalry troops, of necessity had an eye for grass. His enthusiasm for the grassland led him to prophesy:

> I believe that all the flocks and herds in the world could find ample pasturage on these unoccupied Plains and the mountain slopes beyond; and the time is not far distant when the largest flocks and herds in the world will be found here, where the grass grows and ripens untouched from year to year.

At the time Bradley made his prophecy, just 3 years after the close of the Civil War, the Plains were chiefly occupied by herds of buffalo and scattered nomadic Indians. Spotted here and there, but very sparsely, were trading posts established during the gold rush of the forty-niners. Even then changes were taking place swiftly. By 1870 two railroads had been extended across the Great Plains; one from Omaha to the Pacific and the other from Kansas City to Denver. Built primarily to tap the trade of the far West, these roads had a profitable business almost immediately in the transportation of hides, horns, and bones of buffalo that were being all but exterminated. But the byproducts of the buffalo were not the only revenue for the railroads. To the south lay Texas. Cattle multiplied amazingly in this mild even climate. Because of the war, meat prices soared in northern and eastern markets. As a result, by 1885 nearly 6 million head of longhorns had been driven out of Texas over the numerous trails to the railroads.

By the late seventies cattle were spread over a wide area. Actual and prospective profits from the cattle drives caused a phenomenal extension of ranching over the entire Great Plains. Ranges were overstocked, prices slammed down, and ranchers were helpless in the face of inevitable droughts, blizzards, and plagues of grasshoppers.

The railroads, which at first provided eastern outlets for the products of the

Plains, also carried farmers, plows, windmills, and barbwire west. Farmers with their plows gnawed over a wide front at the eastern edge of the Plains, and the large holdings of grassland were quickly broken up.

As the first waves of settlers edged into the dry lands many of them chanced to plow land in wet years. Good crops followed. This reassured some that the agricultural practices of the East could be followed here. And to some it indicated that cultivation was making the country humid. By 1880 Samuel Aughey, of the University of Nebraska, wrote that cultivation had increased rainfall. Others declared that deserts were the result of man's neglect.

But it soon became apparent that adaptations other than those that were appropriate in the humid East were necessary in this country of little rainfall. As haltingly as settlers adapted themselves to their new environment, they made more progress on the whole than did the lawmakers of the East in the land-distribution policy. For up until very recently these land laws were drawn by eastern legislators who had little concept of the conditions in the high, dry country. The present pattern of ownership and use is a result of the homestead-distribution system and the speculation which this system made possible. The early homestead laws, which provided for the distribution of land in 160-acre tracts, were well-adapted to the humid sections of the country but not to the subhumid and semiarid Plains (fig. 4). Even when the homestead acreage was increased to 320 acres in 1909 and to 640 acres in 1916 (for pasture use only) it was still too small in most cases to permit proper use of the land.

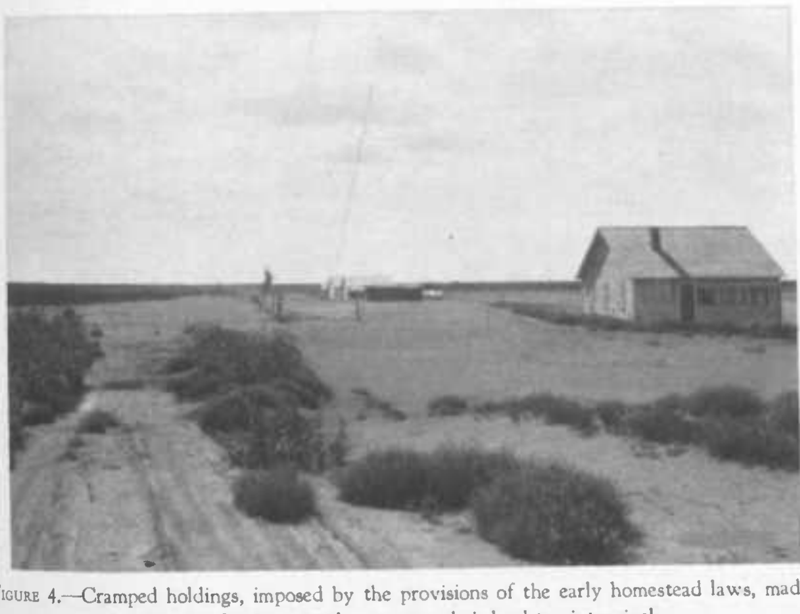

FIGURE 4.—Cramped holdings, imposed by the provisions of the early homestead laws, made it necessary for many settlers to crop their land too intensively.

FIGURE 5.—Steam-driven tractors, once a familiar sight on the Plains, have been replaced by gas-powered outfits.

FIGURE 6.—Harvesting operations were accelerated when the combine came into use. In turn, larger acreages of grain were seeded because more could be harvested with safety.

In at least two respects the public-land policy proved unfortunate. Speculation in land, with its attendant abuses, was accelerated, and the small holdings permitted under the Homestead Acts stimulated overcultivation. As a result the land was used more intensively than the natural conditions justified.

To some historians the American frontier closed in 1890 when the Government ceased to dispose of land lavishly and cheaply. But settlement on new sod continued well into the present century. The peak years of homesteading in Montana were from 1910 to 1917. And this peak was caused principally by four factors: Abundant rainfall, rising wheat prices, the high price of land in the Corn Belt, and an amazing advance in machine technology. Four Montana weather-recording stations—Great Falls, Miles City, Poplar, and Havre—recorded the highest average precipitation up to that time during this period. In 1912 the land office at Havre recorded about 3,000 entries for land; in 1917 it recorded 7,500. The sagging tendency of wheat prices from 1911 to 1913 was abruptly halted by the World War. Food would win the war, farmers were told, and wheat, which normally brought from 65 to 85 cents a bushel, rose to well over $2. "The man was a stoic" wrote M. L. Wilson and Ray Bowden in their bulletin, Dry Farming in the North-Central Montana 'Triangle,' "who could not enthuse over the crops of 1915–16. Wheat on sod without exceptional treatment yielded 50 bushels to the acre and sold for $2 a bushel."

After 1910 other factors, in addition to prices and rainfall, seemed to push the plow and settlement on the grassland. Varieties of wheat were improved in drought resistance, uniformity in growth and ripening as well as yield per acre.

Through the increased use of tractors and other power machinery, production costs were reduced, particularly if the operating units were large (fig. 5). Combines made it possible to seed larger acreages than formerly (fig. 6). Before the combine was used, farmers hesitated to sow more wheat than they could expect to harvest with safety. Horses could be turned on the range, and help could be discharged when not needed, and operating expenses were reduced. But if a man is in debt, cash is required, and the only alternative is to roll out the heavy artillery of production, plow and seed as much land as possible, and hope for rains, a crop, and a satisfactory price.

Debts then seemed to keep wheat growers breaking into sod after rain and good prices ceased. By 1924 the Plains States were growing about 17,000,000 more acres of wheat than they had grown in 1909. While the greatest surge of plows on the grassland occurred in the hard winter wheat areas of Kansas, Colorado, Texas, and Oklahoma, the semiarid section of the more northern spring wheat region from the Missouri west to the Rockies felt the impact.

Some Panaceas

Throughout the period of settlement in the northern Plains, as well as in all other areas of this high, dry country, prosperity has been checkered with good years when rains were favorable and crop failure or near failure when the rains were sparse. The favorable years seemed to lend approval to the farming practices then in vogue. The unfavorable years brought forth theories and proposals which on the surface seemed plausible but proved fallacious when subjected to use by farmers or investigation through research. One system, which involved the dust-mulch idea (sometimes called the Campbell system), had kindled the imagination and raised the hopes of those who were attempting to exploit the agricultural possibilities of the semiarid regions.

The dust-mulch system is old. It was used centuries ago in Mesopotamia, Tunisia, and preconquest Mexico. By 1905 this idea was revived and widely heralded on the Plains. Some people said it would save the agriculture of the semiarid country. A dry-farming congress was held at Denver in 1907 and became an annual affair thereafter for a number of years.

Farmers were taught that the scanty moisture supply could be conserved by keeping the subsurface packed and by maintaining a dust mulch on the surface through cultivation after every summer rain. The Campbell system seemed to work for a time, but dry years emphasized its draw-backs. These draw-backs were called to the attention of farmers as soon as the dry-land experiment stations could test the efficacy of the system. Among the reasons cited for its failure are: (1) Continuous cropping quickly depleted the organic material in the topsoil; (2) frequent shallow cultivation of the surface made the soil vulnerable to the wind; (3) much rainfall was lost as run-off since the soil could not readily absorb water from the torrential downpours that are characteristic of the region.

Exceedingly deep plowing, or subsoiling, is another method that was widely advocated as a panacea for the Plains. The proponents of the idea believed this type of tillage would permit additional water to enter the ground and also increase the zone where crop roots could develop freely. Under trial this theory broke down as a practical measure. Two reasons are usually assigned for its failure. It was too costly to plow so deeply, and the rain that fell between harvesttime and seeding time was often not sufficient to wet the loosened layer. Furthermore, the loosened layer tended to increase evaporation. The net result of this form of excessively deep tillage was that it proved more harmful than beneficial in dry years and of no advantage in wet years. Root growth, investigators found, fully occupied the moist area under normal tillage and was sufficient to use all of the available water under most conditions.

For a number of years a belief has been current that moisture rises from the water table or deep subsoil. This was the basis for the Campbell theory, which sought to trap this supposedly rising moisture near the surface under a

dust blanket. Exhaustive tests show that the upward movement of water, except as carried by plant roots or as vapor, is practically negligible. And tests show that the subsoil within the zone occupied by roots was usually dry at harvest each year irrespective of whether the subsoil below that zone was wet or dry. Despite all of this there is a persistent belief that crop failure on the Plains is caused by the exhaustion of subsoil moisture and the lowering of the water table. In most of the dry-land areas of the Plains there has never been a water table sufficiently near to the surface to quench the thirst of crops even in years of favorable rainfall.

With very minor exceptions, rain and snow from the sky are the only sources of water for crop production. Trite and unnecessary as this statement may seem, there are, nevertheless, many people who cherish the hope that life-giving water may be found from sources other than precipitation. This hope is justified, of course, where water along watercourses may be near enough to the surface to be reached by a deep-rooted perennial crop like alfalfa, and in areas where irrigation water may be used. But the total acreage of areas suited to irrigation is very small in comparison with the vast extent of land that may be used for dry-land agriculture.

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Soil in Motion

ACCELERATED SOIL EROSION is old. It began when rain and wind smote the first furrows turned by prehistoric men. And it has been going on ever since wherever soil has been bared to the elements. But this process is not to be confused with geologic erosion.

Geologic erosion proceeds in a natural undisturbed environment. Vegetation retards the transposition of surface soil by wind and rain to a rate no more rapid, generally, than that at which new soil is formed from the parent materials below. The changes induced in this leisurely process are so slow that they are generally balanced by the soil-building process, and they are so nearly imperceptible that generations of men may never feel the difference.

This is natural balance. But when vegetation is ripped off and the soil pulverized with implements the natural balance is disturbed. And if you continue to cultivate the soil and deplete the spongy organic materials which help to make soils more absorptive you further derange the natural balance. Soil is then removed from the surface much faster than nature builds new soil below, and you have accelerated erosion.

The damage done by wind erosion and that done by water erosion seldom assume an equal degree of importance in any one locality. Soil washing is usually more serious on land that has considerable slope and where the rainfall is intensive (fig. 7). Soil blowing usually becomes severe on both sloping and level areas of low rainfall. Wind erosion may range all the way from a slight disturbance of the surface soil over a small area to the huge duststorms that sweep across many State lines or out to sea.

This dust swirling in the atmosphere is composed of the richest and finest particles of soil. The action of wind on soil is something like that of a sieve. The lighter and more fertile particles are lifted into pathways of high air currents. The coarser and less fertile particles roll and skip over the surface until they pile up as drifts (fig. 8).

Early in 1937 a duststorm originating in the Texas Panhandle traveled northeasterly on into Canada. Dust from this storm came to rest on ice and snow in Iowa and other Northern States. At Clarinda, Iowa, an engineer collected some

of this material and had it compared with samples taken from a small dune near Dalhart, Tex. The dust caught on the snow and ice in southwestern Iowa contained 10 times as much organic matter, 9 times as much nitrogen, and 19 times as much phosphoric acid as the drifting dune sand piled up in north Texas. Analy-

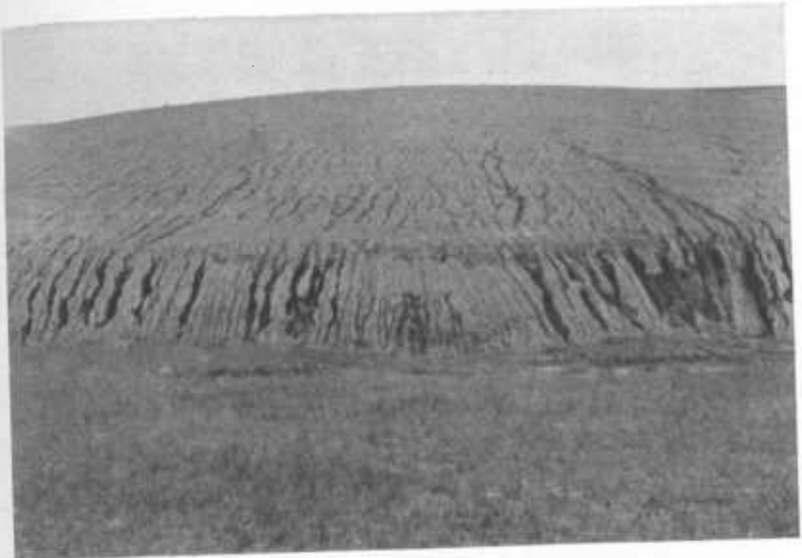

FIGURE 7.—Accelerated water erosion in a Nebraska field.

FIGURE 8.—Accelerated wind erosion in a Montana field.

sis also showed that the transported material contained no sand, while over 90 percent of sand was found in the residual material from the dunes.

While duststorms are dramatic and while the finest and richest parts of the soil are removed, yet the most troublesome aspect of wind erosion is the removal and accumulation of soil that has traveled but a short distance. The degree of removal and accumulation depend on the severity of the wind and the vulnerability of the soil. Light sandy soils, in the absence of sufficient vegetal cover and plant residues, may pile up in dunelike formations. In extreme cases these dunes may, under repeated attacks by the wind, attain heights of from 10 to 20 feet or even more. More frequently the soil drifts are less than 3 or 4 feet in height and are usually called hummocks.

Of course, soils vary in their resistance to the wind, but no soil is immune. Coarse sands are extremely susceptible and usually begin to blow immediately after being plowed. The finer textured soils, and especially those with a granular structure, generally put up the greatest resistance. Even these are subject to wholesale removal if they are under cultivation for a number of years. Under continuous cultivation the organic matter becomes diminished or depleted, the granules break down eventually, and the deflocculated particles are ready to travel with the wind.

In 1900 a North Dakota homesteader near Bottineau broke the sod on all but 40 of his 400 acres. He said:

> In the earlier years we had little wind erosion * * * after it has been cultivated and cultivated it is just an ashpile, and you can pick it up in your hand and watch it float away in dust * * * the fiber is gone out of the soil, and it won't hang together.
>
> It must have been 20 years, anyway, before it started to blow * * * one year I had 80 acres of summer fallow, and the neighbor on the east had 80 acres. You ought to have seen that cloud of dust. The wind hung in the east, and swept that full mile through.

The removal of soil by water erosion can be measured with some degree of accuracy. Numerous experiment stations throughout the country are now measuring the run-off of water and soil under different conditions of slope and cover. The removal of soil by wind erosion can also be measured, but when you have both wind and water erosion on the same piece of land it becomes difficult to estimate the losses caused by their separate action.

A reconnaissance survey of four counties in North Dakota—Bottineau, Renville, McHenry, and Ward—showed that 15.7 percent of the area had no apparent erosion; 67.3 percent had slight erosion; 12.5 percent was eroded to a moderate degree; on 2.8 percent the erosion was classed as severe, while 1.7 was very severely eroded.

While most of the erosion in this area is caused by the wind, serious water erosion is found on sloping areas of medium-textured and light-textured soils.

Hard red spring wheat is the main crop in this area. More than 67 percent of the land is cropped; 25 percent is in grass; and the remainder is in idle land

and woodland. Practically all of the land now used for grain production has been broken from native sod since 1900.

Information is not available to indicate the damage to the northern Plains soils as a whole by wind erosion. There are, however, light sandy areas that have been essentially destroyed so far as their value for cultivated crops is concerned. When surface soil is removed to plow depth the portion which contains most of the organic matter, most of the available plant food, and the absorbing capacity for water, is lost. When drought periods return, as they always do, such soil cannot produce crops for profit or for protection against erosion to the extent that it would have if erosion had not injured the land.

Older farmers in the region have seen duststorms and soil drifting prior to the severe distress of the early and middle 1930's. Some of these farmers, particularly those who have silt loam or silty loam soils, advance the view that these soils are just as productive after the surface soil is removed as before if good rains come. True, many of these fields will grow bumper crops if well supplied with moisture. During droughty periods and crop failure, plant food is not removed but tends to accumulate. And many of these soils have some humus or organic matter in the upper part of the subsoil. Such soil if moisture is available might readily produce high yields for a short time. But one cannot expect such soils to continue to be highly productive if they are subjected to repeated punishment by the wind.

Controls and Cures

IT IS CLEARLY EVIDENT that the duststorms and soil drifting on the Plains are the effects from a wide variety of causes. And it follows that no one prescription is adequate to solve a problem so complex. The goal everyone seeks is an amelioration or prevention of distressing emergencies. This is not to imply that the Government—Federal-State-County—should not make every effort to relieve destitute families and give aid as it was given prior to and has been given since the distressing period of the 1930's. This is taken for granted. But what enlightened citizens now seek is the development of an economy that is in harmony with the natural adaptations of the country. Probably the greatest single dry-land problem is to adjust the entire farming system to a production that may be expected over a long period of years.

Land Use Adjustments

Much of the trouble on the northern Plains stems from the unwise provisions in the first homestead laws, which denied prospective farmers enough land to provide a fair standard of living. Since they had too little land they could not build reserves sufficient to carry them through the drought and drought cycles that are normal for the Plains. Many were forced to crop land that was ill adapted to cultivation. Moreover, they had too little grazing land to provide sufficient revenue from livestock. This mistake in the past must be laid at the Federal doorstep. Blame for other mistakes must be borne by individuals and their inexperience in handling problems that are characteristic of a semiarid country. An occupational tally of Hill County, Mont., by M. L. Wilson in the early 1920's revealed that less than half of the settlers had previously been farmers and that 30 percent had arrived with no capital. The list included musicians, butchers, a bartender, a miner, deep-sea divers, maiden ladies, merchants, preachers, plasterers, peddlers, gamblers, and jacks-of-all trades.

But failures are not confined to the inexperienced. Numerous examples of failure may be found among experienced farmers, and it is generally agreed that a lack of sufficient land is the chief cause. Though droughts have recently enforced migration, many families are still struggling on cramped holdings. Nonresident owners have the choice of paying taxes from sources other than the land or permitting it to be returned to the Government. If tax-delinquent land is returned to public ownership the problem is still unsolved. It is merely shifted to officials who are charged with the administration of these lands.

Problems related to the appropriate use of the land have been under consideration for a number of years by various arms of the Federal Government as well as by States and counties. Various policies have been put into action. And on the whole progress has been made. More recently steps have been taken to coordinate the policies of the several governmental units in a more workable combination to the end that greater speed may be attained in making land use adjustments.

These adjustments are most urgent in those areas where the soil is so vulnerable to erosion that it is unwise to risk its use for further cultivation even if water conservation and other appropriate farming practices are applied. Obviously, this land should be retired from cultivation as quickly as possible (fig. 9). There are other lands that can be cultivated to a limited extent if appropriate farming practices are brought into use. There are still other lands on which the cultivation of crops can be pursued as the principal source of revenue if due

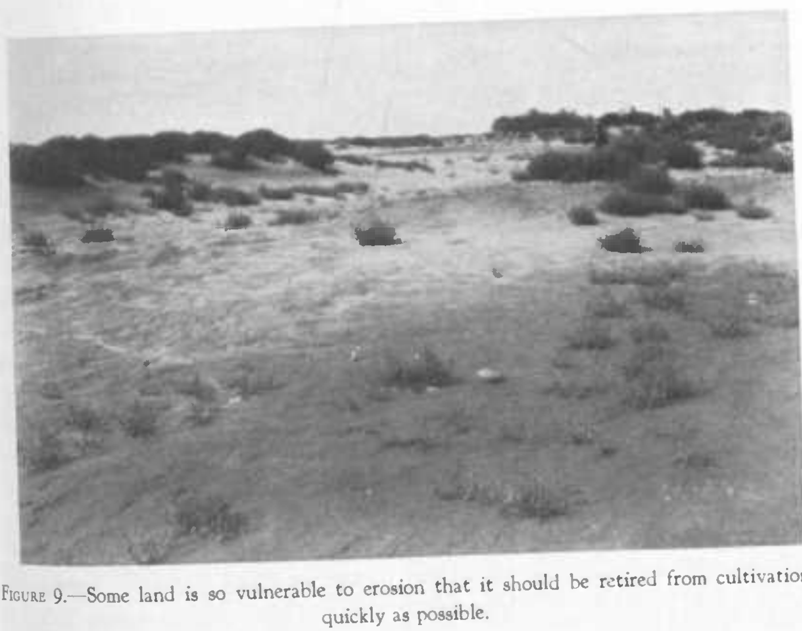

FIGURE 9.—Some land is so vulnerable to erosion that it should be retired from cultivation as quickly as possible.

Figure 10.—Cultivated crops may provide the principal source of revenue on some lands permanently if they are handled judiciously.

regard is given to the practices followed (fig. 10). But even on these lands it is usually wise for the operator to have some livestock to utilize grass and other feed crops.

Since land varies considerably in its productive value, it is apparent that some form of land classification is necessary to make the proper adjustments. Classification can be made only on the basis of adequate surveys. Fortunately, in some areas the experience of farmers and ranchers as well as rather complete surveys by State colleges of agriculture, the experiment stations, and other governmental agencies, provide adequate information to complete the classification. There are other areas, unfortunately, where more information is required to determine how much land lies in each of the categories.

One of the more recent action programs of the Federal Government designed to correct maladjustments in submarginal farming areas is the land acquisition and development program of the Department of Agriculture. This program is directed primarily toward changing, by means of public purchase, existing patterns of land use which cause or are likely to cause a waste or misuse of land resources. The term "retirement" implies shifting land which is submarginal in its present use to a wiser use. In general, this usually involves a shift from cash-crop farming to grazing or to a combination of the two.

The retirement to grass of lands unsuited to cultivation makes it possible to shift from cash crops to a combination of the livestock and feed-crop type of farming. The purchase of some of the smaller units will give the operators

who remain additional grazing land and so enlarge the operating units to the point where a reasonable standard of living may be maintained.

Under public control the range resources can be safeguarded. The Government-owned land may be leased to associations under conditions and regulations that will maintain or improve the grazing capacity of the range. The grazing associations can also apply regulations to private lands under their control and thus extend the application of control measures.

The land use adjustment project in Campbell County, Wyo., briefly discussed in the next section, will illustrate some of the major changes made through an acquisition and development program. Similar changes are being made in 19 other areas in which the Soil Conservation Service is cooperating with State and local agencies and with ranchers in the northern Great Plains.

Spring Creek Area, Wyo.

The Spring Creek area, approximately four townships in size, is part of a large strip of land in eastern Wyoming where similar conditions of land use prevail. Prior to 1919 most of the land was used by large stock operators. But high prices and unusually favorable rainfall from 1919 to 1922 induced extensive settlement on this land that is primarily suitable for grazing. Two years of crop failure followed. Good rains brought paying crops in 1925, 1926, 1927, and 1928. But since that time crop yields have been almost negligible. Despite these unfavorable years settlers took up land until the closing of the public domain to homestead entry in 1934.

Recognizing the futility of cash-crop farming, many operators had attempted to take up stock raising. But this endeavor was held in check since most of the landowners had title to an average of only 747 acres. Far more acres were needed for a stock farm, and the difficulty was increased by the confused pattern of ownership. Many tracts had been abandoned, and the owners were difficult to locate. Furthermore, having little capital, because of crop failures they were forced to rely on leases to obtain the needed land. Leases, for the most part, could be obtained for only 1 year, and this prevented the operator from attempting any constructive plan to improve grass or livestock. By 1934 the operating units in the area averaged only 1,700 acres, which is less than half of what is considered desirable for this locality.

Since 1934 a three-point program has been under way in the area. The three points were the purchase of submarginal land consisting of unsuccessful operating units, the development of the land for grazing, and a cooperative plan of management and operation of the land through the formation of a cooperative grazing association.

The Government purchased 41,280 acres. Of this, 35,452 acres were purchased from 48 owners, and 5,828 acres were obtained from relinquishments

on 11 homesteads. All of the purchased land was voluntarily offered for sale by the owners. By buying the holdings of 27 of the 54 operators in the area sufficient land was made available to provide an adequate operating unit for the 27 operators who remained. When the land was reallocated the average size of the operating units was increased from 1,700 acres to 4,760 acres. Operators on the enlarged holdings can now qualify for loans with which to improve their herds and buildings.

Stock reservoirs and spring developments, along with the relocation of fences to facilitate the management of the range, were among the major developments along the realignment of operating units.

Perhaps most important are the provisions made for the management and conservation of the range. Land owned by the Government is now leased to individuals through a cooperative grazing association. The Spring Creek Cooperative Livestock Association, consisting of 22 stockmen was formed in November 1936. This association leases all Federal- and State-owned land. It also leases such absentee-owned lands as are not under direct management of a member of the association. Either directly, or through its members, the association therefore controls all land in the 4 townships.

The association issues a grazing permit to each member, stipulating the conditions under which the range is to be used and the number of livestock that the member is entitled to run. A fee is charged for each permit. The amount is based on the number of livestock grazed on the association's land.

The federally owned land has been leased to the association for 10 years. The fee for each current year is based on the prevailing prices of livestock, livestock products, and the general condition of the range. The carrying capacity of all range under the control of the association is determined each spring by the Soil Conservation Service. The association agrees to keep the number of head grazed within the limit set on the basis of carrying capacity.

In general, the activities of the association bring the area under organized management, so that present operators feel a far greater stability than they did previous to the purchase and development program.

Of the 27 operators whose farms were purchased, 5 have located on farms outside of the area in eastern Wyoming; 8 have located on farms in other States; 3 have taken nonagricultural jobs; 3 are working as hired hands on nearby ranches, and 2 elderly people have retired and live with relatives. One man of foreign birth has returned to his native land. One died shortly after selling his farm. The situation of the 4 remaining families is not now known.

Saving the Water

Effective permanent efforts toward erosion control must center around the maintenance of a good vegetative cover. This means continuous cover on range

lands and during critical periods on croplands. Vegetation and its use affords the only means of providing a livelihood for those who live on the land. The key to vegetation is water (fig. 11). Without water there can be no vegetation, and without vegetation there can be no practical way of keeping the soil in its proper place. Usually enough water falls on the Plains to provide some vegetation and a partial crop, if none is wasted. Good land use, therefore, requires the retention of rainfall moisture as the first step in protecting the soil against erosion.

FIGURE 11.—Water is the key to vegetation on the Plains. These contour furrows held all of the water that fell in a 1-inch rain.

By and large, the farmer who practices conservation measures may get as much benefit from a 2-inch rain as another farmer gets from 3 inches if the latter does not practice conservation measures. Or stated in another way, the farmer who saves all the rain that falls may be able to sink water at least a foot deeper than the farmer who allows part of the rainfall to escape as run-off. This extra foot of water penetration may mean the difference between a fair or good crop and a partial or complete failure. Every successful crop avoids an erosion hazard.

Conservation of moisture in the Plains is more important now than formerly. When the soil contained relatively large amounts of humus considerable water was retained for the benefit of vegetation. Now with much of the water-holding and water-absorbing capacity reduced, it takes a greater rainfall to give the same benefit in crop production.

Speaking of his boyhood farm home in east-central Nebraska, A. E. Jones said:

This was a wet country when my father came here out of Iowa. I remember hearing him say, "There is a good piece of land—it is well drained." Father and mother farmed that place for a

number of years. They educated their children from that land and they are in complete comfort now. But father could raise 50 bushels of corn on a 29-inch rainfall while the man on the place now can scarcely raise 25 with the same amount of rain. It is entirely evident now that one of father's three eighties should have been in grass. But he couldn't have put one of those eighties in grass with the exploitative system of farming going on all around him. We madly produced everything we could.

The manager of 17 Red River Valley farms in North Dakota said:

There have been changes in this country around here in the last 5 years, and more in the past 10 years. We have been using a hit-and-miss system of farming our land, and not getting the results we used to. We have to adopt different methods to get what we had 5 or 10 years ago. We must get away from the old routine of "buckshot" farming, plowing, harrowing, and drilling.

In emphasizing the importance of saving water in dry-land sections of the Plains it is important to remember that a considerable quantity of water is required before a measurable yield of crops is produced. Yields, up to a certain point, are in fairly close relation to the quantity of water above the minimum requirements. O. R. Mathews and J. S. Cole, of the Bureau of Plant Industry, explain this point as follows:

Assume that in a certain section a precipitation of 10 inches represents the minimum requirement for wheat to produce grain. Under this condition a 9-inch precipitation would result in complete failure, but a precipitation of 12 inches would produce some grain. The difference in yields is not proportional to the amount of precipitation. It is the difference between no crop and a light crop. A precipitation of 14 inches would produce, not one-sixth more, but double the yield produced by a 12-inch precipitation, as there would be twice as much water above the minimum requirement.

This explains the value of comparatively small quantities of water in dry-land farming. The value of fallow and other moisture-conserving practices is all out of proportion to the quantity of water stored as compared with the total quantity required for crop production. This is because the additional water contributed is generally above the minimum requirement. Over the Great Plains as a whole the value of 1 inch of conserved water is from 3 to 4 bushels of wheat per acre, provided the precipitation is sufficient to meet minimum requirements.

That there is a close relationship between the amount of water in the soil at seeding time and the yield at harvest has long been established for winter wheat in the southern Plains. More recently exhaustive tests with spring wheat in the northern Plains show similar results (fig. 12). At the several experiment stations in the drier parts of the northern Plains the chance for a profitable crop is found to be very small when the soil is wet down but 1 foot. Soil wet 2 feet in depth affords a fairly good chance of a crop, and soil wet to a depth of 3 feet affords a fairly good assurance of a satisfactory yield.

Remembering, always, that no miracle can produce a crop without water, one must focus all appropriate dry-land practices on means for making the most efficient use of the limited rainfall. There are three principal ways to make more efficient use of water. One is to prevent run-off either partially or entirely; another is to reduce evaporation; and still another is to make sure that weed

growth does not dissipate the soil moisture that otherwise might be used for crops on cultivated lands or for more desirable pasture grasses on range land.

One of the newer methods of preventing run-off or keeping water evenly distributed on the Plains is to conduct all farming operations on the contour. Map makers think of contours as lines which join points of equal elevation.

FIGURE 12.—Usually, a close relationship exists between the depth of moisture at seeding time and the yield of grain at harvest. These men are testing the depth of moisture penetration.

FIGURE 13.—Up-and-down-hill farming permits quick and serious losses of soil and water.

Farmers who till their fields on the contour think of going across the slope of the land on the level and never up and down hill as it is necessary to do when farming parallel to or at right angles to conventional boundary lines.

Up-and-down-hill farming of necessity leaves troughs or drains that carry soil and water during and after heavy rains (fig. 13). If slopes are long, the water in seeking the lowest level will travel a considerable distance. In traveling this distance both the volume and speed have increased, and a corresponding amount of soil is carried along. In humid areas losses of soil may be more critical than those of water. But here on the Plains the water loss is the most disasterous in most instances.

Contour farming permits water to sink into the soil at or very near the spot where it falls for crop use. Whether the entire amount of rain and snow can be held where it falls will depend on the rainfall, the type of soil, and the capacity of the furrows to hold water temporarily.

Practically all of the tillage tools on the Plains become more effective for water conservation if they are used on the contour. And this applies to such a tool as the basin lister which leaves frequent cross dams in the furrows (fig. 14). If there is any considerable slope to the land and the basin lister is not used on the contour, there is a possibility that water will break over in spots and cut channels down the slope. Occasionally a field will be hummocky or otherwise of such topography that it is impossible to have tillage rows on the true contour. In this event, the basin lister becomes more effective than a tool that leaves no cross dams in the furrows.

FIGURE 14.—When snow thawed on this field in 1937 each basin held the water until it could soak into the soil. There was little or no run-off of water and soil.

Strip Farming

Of the conscious devices for the protection of soil against erosion, strip cropping is perhaps the most widely practiced. A few farmers in eastern Ohio and western Pennsylvania have protected their fields by some form of strip cropping for a half century. More recently spring wheat growers in Alberta, where fallowing has been practiced for a number of years, have used wind strip cropping for soil protection. Shortly after the sod was first turned these farmers noticed that the last place to drift was a strip of soil on the side of the fallow field toward the prevailing wind. This observation gave them a suggestion. Why not divide the land into strips of equal width running crosswise to the prevailing wind? Each alternate strip would be in wheat one year and fallow the next.

In recent years, since soil blowing has become a more serious problem in the spring wheat region of the northern Plains, this type of crop barrier has become quite common in some areas. In some sections, and particularly where fallowing is conducted, one can ride for miles and seldom see a whole field in wheat or a whole field in fallow; all are broken into strips with wheat or fallow in alternating bands. At first farmers were inclined to make these strips from 30 to 40 rods or even more in width. They noticed, however, that fields with narrow strips drifted less than did those with wider strips. This observation led to narrower strips. Most of them now are 10 rods or even less in width.

This form of strip cropping, first practiced by farmers in the Monarch district of Alberta and later by farmers in the northern Plains, is perhaps the simplest form of the many methods of using strip cropping. This simple system has been found useful on the comparatively level lands. But if there is any considerable slope to the land and where run-off losses of water are serious, strip cropping should be conducted on the contour. In this case true contour strips, with every cultivated band on the level around the slope, are preferred. Then, whether the rotation is grain and fallow, corn and sweetclover, grain and corn, or whatsoever alternating combination of open or row crop and close-growing crops are used, maximum protection to the soil is assured, both from wind and water action (fig. 15). The wind finds no large exposed area to disturb, and the additional moisture held in the soil tilled on the contour enhances the growth of crops. The speed of water moving down the tilled slope is checked to a harmless pace by the level closely vegetated strips. These strips also strain out any of the valuable topsoil that the water may have started to carry off the open or cultivated strips.

Inevitably when a rolling field is strip-cropped on the contour the operator is confronted with the point-row problem if row crops are included in the rotation. To meet this problem many farmers in conservation-project areas provide permanent buffer strips of vegetation which take up the unevenness in width be-

tween the different strips (fig. 16). In this way all of the strips that are cultivated or that will be cultivated in the course of a rotation are of an equal width, and point rows are eliminated.

Although strip cropping is effective as a method of preventing soil and water loss, there are some conditions under which it may not be successful. On extremely sandy lands the soil may drift into the crop strips and an irregular surface condition of the field result. In most cases these soils should be kept in some type of perennial vegetation, or the choice and sequence of crops should be so arranged that the field will be protected by either a growing crop or crop residues throughout the year.

In some seasons hot winds and grasshoppers and other insects may cause greater damage than in solid fields. On the whole, however, when farmers have been disappointed with the results from strip cropping the disappointment usually can be traced to the idea that strip farming alone would prevent soil blowing regardless of the condition of the soil. Good tillage practices are just as essential with strip farming as they are under ordinary conditions.

Strip farming is a flexible method. If fallow, for example, is to be used 1 year out of 3 (instead of 1 year out of 2) the field could be divided into strips of equal width and then two of the strips used each year for wheat and the third for fallow. In this case each strip would be summer-fallowed every third year.

If row crops are grown, the row crop may replace fallow in alternate strips with small grain. In a three-strip sequence one strip could be used for a row crop, an adjoining strip for fallow, and the third for wheat. The inclusion of

FIGURE 15.—Strip cropping on the contour protects this Nebraska farm against wind and water.

FIGURE 16.—An Oklahoma farmer said he liked farming on the contour because it made it difficult for creditors to find him while he was doing his field work. The buffer strips of permanent vegetation, as shown in the Montana field above, make it unnecessary to cultivate point rows.

row crops in the strip-farming plan, however, is desirable in areas where diversification with livestock can be accomplished.

Most of the discussion about strip farming does not center on the principle involved but on the width of strips. Width of strips is determined by a wide variety of conditions such as the type of soil, the slope of the land, the cropping system, and the tillage and harvesting machinery that is used. Unfortunately there is little closely calculated information on the proper widths of strips under various conditions. Since strip farming is a flexible method the widths can be increased or decreased with little inconvenience.

Tillage

Tillage tools now in use on the Plains may be divided into two main groups. One group, in general to be shunned, includes those tools which are designed to level, pulverize, and powder the surface soil, leaving crop residues completely or nearly submerged. Within this group are such tools as the spike-tooth harrows, rollers, surface packers, and disks. Tools of this type came into general use throughout the Plains when the dust-mulch theory of conserving moisture was widely advocated.

The other group of tools includes those which dig deeply, raise big clods, and leave as much crop residue as possible on the surface. In general these are the

newer types of implements, and they represent a conscious retreat from the earlier tools, which left the soil in a condition to blow if winds came or in a condition to lose water as run-off after heavy rains. Among the improved tools are the lister, the subsurface tiller, the chisel, the duckfoot cultivator, the rod weeder, the hole digger, and others.

The moldboard plow is used extensively in the northern Great Plains. Under certain cropping systems and on soils which will clod, leaving the surface rough, this implement is considered desirable. The moldboard plow, however, has the disadvantage of turning under all crop residues and leaving the surface bare. When used on the lighter type of soils, where a cloddy surface cannot be secured or maintained throughout the fallow period, its use may permit excessive erosion.

Within comparatively recent years the "one-way" plow has replaced the moldboard plow in many areas. It is often considered a good implement for the first tillage operation as it leaves a large portion of the residues on the surface. However, the one-way plow has been misused for subsequent weeding operations during the fallow season, with the result that surface residues are destroyed, the surface soil is finely pulverized, and erosion is greatly aggravated. The duckfoot cultivator, rotary-rod weeder, and similar types of implements are more desirable for secondary tillage operations. If there is a light stubble cover or lack of corn following crop failure, the use of the one-way plow for the first tillage operation is not advisable.

During the past few years much attention has been given to improving tillage implements for use under dry-farming conditions, and many promising developments are now under experimentation and demonstration. The principal features embodied in these new tools are those that tend to leave all or most of the crop residues on the surface or to leave the surface in a roughened condition. Some of the recent developments along this line include the subsurface blade and sweep-type implements, the modified moldboard and lister bottom plows, and modified disks. Other implements have been designed principally for roughening or waffling the surface to hold more of the water where it falls until it can be absorbed by the soil.

While all of the newer types of implements represent progress in adaptation for use on the Plains, many farmers have found ways of using some of the older tools in more desirable ways than formerly. Some have converted one-way plows into tools that perform work similar to the basin lister (fig. 17). Other farmers have removed the mold-board from their plows. Still others have cut the wing from the rear end of the moldboard. For summer-fallow cultivation some farmers use large shovels on ordinary duckfoot cultivators. This tool leaves the soil in the condition shown in figure 18.

A few farmers in the Soil Conservation Service project area near Bottineau, N. Dak., have replaced worn disks on disk harrows with 20-inch disks which

FIGURE 17.—Twenty-six-inch disks with 8-inch notches were used in converting this one-way plow into a machine that works similarly to a basin lister.

FIGURE 18.—Large shovels may be used on duckfoot implements for the cultivation of fallow land The altered tool leaves the soil ridged and cloddy.

have a $1\frac{1}{2}$-inch cup, or dish. These larger disks with less dish leave the stubble anchored almost upright in the surface soil.

Terraces

Of various methods of soil-saving strategy the world over, terracing perhaps has been the most widely used. In the Orient, Central America, parts of Europe, and elsewhere, various types have been in use for hundreds of years. In America, terraces were first tried in our southeastern Atlantic coastal States. Farmers there in desperation sought feasible methods of holding soil that was opened to the weather through continuous cropping with tobacco and cotton. Terraces in America, however, differ considerably from the Old World structures that most of us saw pictured in histories and geographies during our youth. Those old pictures usually showed vertical walls of masonry, or at least a very steep grass-covered riser, between benches of soil where the crops were grown.

Apart from these early earth embankments of the Southeast and the few benchlike structures later etched on steep hillsides of Lower California, few terraces have been used in American agriculture until very recently. Now that we are more earnest in saving soil and since there is no new land to surge upon, terracing is finding a place as a control measure west of the Mississippi and north of the Mason and Dixon line.

Since water conservation and soil conservation are inseparably combined, terrace embankments may serve both purposes in a field. In a region like the Great Plains, where there is usually little or no surplus water above crop requirements, the water-retention feature of terracing is very important. To meet this objective and to be workable with the large farm machinery of the Plains, a special type of terrace has come into use. These terraces have a broad base and are usually constructed with closed ends where the slopes are less than 1 percent. If the slope exceeds $1\frac{1}{2}$ percent the ends are usually left open, or drainage terraces are used. The open-end terrace embodies the water-conserving features of the closed-end terrace but to a less degree as it is a compromise between maximum water retention and the safe disposal of run-off as secured by the drainage-type terrace. The choice of use of the level terrace with either closed or open ends and of the drainage-type terrace is governed by the kind of soil, slope, character of rainfall, and land use. Often run-off from rough land or from a highway may be picked up and spread on relatively level cropland or grasslands. In this case the alternate ends of terraces are left open, and the surplus water is marshaled back and forth across the field between terrace ridges in sirup-pan fashion.

Terraces are comparatively costly to construct in a field. At the present time most of the north Plains engineers and agronomists believe that terraces will find their greatest usefulness in eastern Nebraska and southeastern South

Dakota. In these areas total rainfall is greater and a larger proportion of the land is under cultivation than in the northern Plains as a whole. Furthermore, the extensive production of cultivated crops, particularly corn, in the loess fill and drift hill regions make some mechanical method of control necessary to prevent damage from the extremely heavy rains that are common. And even though some storms are heavy, total precipitation during the growing season is usually so low that there is every need to conserve as much of this moisture as possible for the benefit of crops.

While many farms in this area are punished by continuous cropping with cultivated crops, there has been a rather widespread use of rotations including sweetclover and alfalfa. Use of these soil-building crops is a marked improvement over the continuous use of cultivated crops, but it is apparent that the greater use of legumes and grasses in more or less regular sequence with the cultivated crops is needed to control erosion and maintain fertility.

The diversion type of terrace, which represents a compromise between a complete terrace system and none, has been found useful to ease water off higher land. These structures are usually larger than the regular terrace and are laid on a steeper gradient so as to carry more run-off. They are often placed at the foot of pasture slopes lying above cultivated fields in order to divert and carry water safely to established drainage courses and thus prevent it from running down across the cultivated land. Occasionally terraces of this type are constructed in a cultivated field to supplement contour tillage, strip cropping, and other control measures.

The trend toward the manufacture of implements that are more flexible and maneuverable will facilitate the farming of terraced fields. Such implements as the mowing-machine attachment for a tractor, and corn planters and cultivators that are closely attached to tractors, are making it easier to farm steep and irregular fields which have been terraced.

Where applicable, terraces are but one of many elastic combinations of control measures that may be used on a field. Control measures support each other. Terracing makes vegetative control more effective, and vegetative control makes terracing more efficient.

Fallowing

Summer fallowing for the production of crops has been widely practiced in the semiarid sections of the northern Great Plains. The practice involves allowing land to lie over the season in a cultivated condition, and without being cropped, to permit moisture to accumulate for use by the crop the following year. Its value in any given section depends upon the extent to which it will increase yields and reduce failures as compared to other methods which might be used. To be economical, fallowing must result in materially increased yields as no return

is received the year the land is in fallow. Thus, its advantages are greater in the drier sections than in the humid sections of the Plains because in the drier sections annual precipitation is usually below that necessary for a maximum yield and often below the minimum required to prevent a complete failure. Most farmers in the spring wheat section of the north Plains handle a fallow by permitting the stubble from a crop to stand over winter and then plow in the spring before weeds have dissipated much water. During the summer the land is kept free of weeds but in a roughened condition and ready to absorb rains, which usually come in May and June. It is advisable to delay plowing in the spring until weeds are well started but are not yet using water rapidly. Early spring plowing has no advantage, and it increases the number of cultivations needed to keep the land free of weeds during the summer. If plowing is delayed too long, however, there is serious loss of water because of the weeds.

More recently, and especially since soil blowing has been generally prevalent, the plowless fallow has come into use. Under the plowless-fallow system the land is prepared with implements that destroy weeds without turning the stubble under. Usually the plowless fallow requires a greater number of cultivations, but it is generally less expensive than plowing, and the stubble helps to prevent soil drifting during the following winter.

With either plowed or plowless fallow it is possible to hold only a small proportion of the year's rainfall. Evaporation from the surface following summer rains accounts for much of the water that cannot be made available for deeper penetration. Experiment station findings on the use of fallow show that only 20 to 25 percent of the average rainfall can be stored.

As with all farming practices there is a wide difference in the results obtained from wise and unwise methods of maintaining a fallow. A good fallow is obtained by handling the land in such a way that moisture is conserved, weed growth is prevented, and the surface is resistant to erosion. If weeds are allowed to use a portion of the water the fallow system is expected to save or if the soil is cultivated in such a way as to leave the surface fine and loose, then failure is imminent. There is little chance of obtaining a crop for profit or soil protection if weeds get the water. On the other hand if the soil is loose and without a cloddy surface it becomes an easy prey to the first strong winds. The danger involved in unwise fallowing has caused those who believe in it most to hesitate in recommending its general use.

On some soils, particularly the light sandy types, no method of bare tillage will give adequate assurance against soil drifting if conditions are unfavorable. On these soils it is very difficult to raise clods. And most farmers find that these soils can be held only by a protective cover throughout the year. Under these conditions the plowless fallow is indispensable. Otherwise the only alternatives are continuous cropping with spring grain or returning the field to a permanent cover of grass or legume.

In some places where wheat has been grown in a fallow system, conditions may warrant replacing the fallow with a row crop such as corn or sorghum. The yield of wheat following corn is normally only a little less than the yield of wheat following fallow. By combining corn or sorghum with wheat the operator is enabled to carry some livestock. Some farmers are finding that they can make a light seeding of corn with rows 84 inches apart or spaced to fit their tillage tools. This reduces the effectiveness of the fallow very little, and they get practically the same yield of wheat as under a complete fallow system.

Trees on the Plains

Until recently much of our information pertaining to windbreaks originated in Europe. Comparatively, only a small amount of such information has accumulated from reasearch and experience in the United States.

Within the past 20 years the northern Plains field stations of the Bureau of Plant Industry have made more than 4,000 plantings for observation. Our Canadian neighbors through the Canadian National Forest Service have made similar studies. More recently the experiment stations and extension services of the northern Plains States have accumulated helpful information. And still more recently our fund of knowledge has been augmented through the extensive plantings made by the Forest Service in the Prairie States Forestry Project and by the Soil Conservation Service. Perhaps most significant of all is the experience gained by farmers.

FIGURE 19.—This windbreak of cottonwood, ash, and boxelder was planted in 1887.

Some of the windbreaks planted by early farmers still survive although many have failed (fig. 19). While the successful plantings are outnumbered by those that have failed, the failures, nevertheless, help to prevent mistakes in the future. A successful attempt can be found in Pierce County, Nebr. This particular windbreak was planted in 1887 and consists of a 10-rod strip of cottonwood, ash, and boxelder.

Most of these early windbreaks were not planted with the idea that they would help protect soil or crops against the wind, for soil blowing was not then a serious problem. Probably most of them were planted for the protection of man

FIGURE 20.—These fast-growing cottonwoods in North Dakota practically doubled their height during the year preceding August 1937, when the picture was taken.

and livestock around home sites. We know now that trees, if properly integrated with other control measures, can help to prevent soil blowing and the loss of crops.

Windbreaks are usually from 5 to 10 rods in width and are located on the border of cultivated fields. Widths of less than 5 rods are not recommended since the trees in narrower strips cannot be expected to maintain themselves indefinitely. The composition of the planting in the eastern part of the Plains is made with an eye toward the attainment of typical forest conditions so that trees will reproduce themselves naturally (fig. 20). The planting includes outer borders of hardy shrubs and a variety of trees within. The taller, faster growing trees are planted in the center. The slower growing and spreading varieties are planted between the center rows and the outside shrub rows. The entire planting forms a gradually rounded cross section from the outer shrub borders to the center.

Trees and shrubs growing in a pattern such as this will usually exert a protective influence for from 15 to 20 times their height. There are several beneficial effects. Soil blowing is materially reduced, but the improvement of soil-moisture conditions in adjacent fields is equally if not more important than the direct protection of soil. Snow is retained on the ground where it falls. The next spring the snow melts and water soaks into the soil. One of the most apparent effects is the protection of crops against hot winds.

There are, of course, some detrimental effects from windbreaks. Tree roots will extend into the adjoining cultivated land and take moisture that would otherwise be available for growing crops. Beneficial effects, however, usually outweigh those which are detrimental.

An auxiliary measure is occasionally used in connection with field windbreaks. On large farms, and on those where the soil is most vulnerable a single windbreak may not provide adequate protection. In instances such as these, narrower plantings of buffer strips are frequently provided. These strips may consist of one, two, or three rows of trees and shrubs or of shrubs alone. Since the trees and shrubs for such narrow plantings cannot be expected to reproduce naturally, the most hardy species should be selected.

FIGURE 21.—Properly selected varieties of trees on favorable sites may grow west of the 18-inch-rainfall line if given good care. This Wyoming woman is pointing to the top of the Chinese elm that she planted 12 years ago.

Perhaps more frequently than any other factor lack of proper cultivation leads to the failure of trees on the Plains. Clean cultivation is required for the first 3 to 5 years or until the crowns of the trees are sufficiently closed to shade out weeds and grass.

No attempt is made here to cover all of the require-

ments that are necessary to establish trees. East of the 18-inch rainfall line trees may be expected to thrive if reasonable precautions are used. West of the 18-inch rainfall line more exacting attention must be given to soil, cultivation, and site conditions than is necessary to the east (fig. 21). In this arid area trees cannot be expected to thrive unless all the water that falls on the planting site is conserved, and in some instances additional water has to be provided by diversion structures or by irrigation.

In an Emergency

Possibly there will be some years on the Plains, as there have been in the past, when all-round good farming practices will be insufficient to provide a vegetal cover or enough crop residue to prevent soil blowing. When crops fail generally, in spite of the use of water-conserving and other recognized good-farming practices, the Plains farmer has at his disposal other measures, although expensive, of holding soil.

He can hurry out to his fields as soon as small areas begin to blow and throw up emergency barriers against the wind. If action is delayed and the area is permitted to become large, it may be impossible to check soil blowing.

When a field is smooth and without a protective cover it should be watched throughout the season, and when blowing starts measures should be employed to check the movement of soil. In an emergency, tillage methods are the only ones to depend upon. The type of implement is of relatively little importance, but the surface condition left by an implement is the main concern.

Most farmers probably prefer the lister for emergency work on medium to heavy soils. To be effective the lister must lift clods to the surface. Otherwise listing may be of little or no value. On sandy types of soil the lister is usually of little benefit.

Under some conditions the chisel may be more valuable for emergency tillage than the lister. When a field is hard or when it has been coated with 3 or 4 inches of soil from previous duststorms and the lister fails to bring up large clods, then deep chiseling may be better than listing.

The moldboard plow may be used under some conditions, but it is usually necessary to plow quite deeply and to throw two or more furrows together to form a ridge of coarse material. If an entire field is plowed with a moldboard plow, only small traps are provided between the furrow slices. These will soon drift full, and then blowing may become general over the entire field.

If the soil-blowing hazard is not great there are other tools that may be pressed into service. Among these tools are the duckfoot cultivator, spring-tooth harrow, shovel cultivator, and others. But these implements are inadequate to cut deeply and lift large clods and are, therefore, unable to provide protection to the soil over any considerable period of time.

If there is any real slope to the land all of these tools should be used on the contour and preferably before the wind starts to move the soil. When tillage is completed before the blow period the farmer has an opportunity to follow contour lines with his implements. In this way he is ready for either rain or wind. If rains come he can be reasonably sure that his field will catch and keep most of the water that falls. If the winds blow severely he can rely on his deep furrows and large clods to trap most of the soil before it moves far.

All of these methods are only "stopgap" efforts to hold soil during an emergency. In a sense they should be used much as one uses a spare tire on an auto. Obviously it is expensive to run a tractor or use a team to throw up emergency barriers against the wind. The point of view here taken is that fields should normally be so well protected with a cover of crops or crop residue that emergency measures are unnecessary.

To help forestall these emergencies one must make sure that stubblefields and stalk fields are not overgrazed or burned and the protective value of crop residue thereby reduced. Severe trampling of stubblefields or stalk fields may pulverize an otherwise well-anchored soil.

Regrassing

Farmer experience and experimental research support the belief that the only permanent remedy for the control of wind erosion in the most critical areas is to establish grasses that are sufficiently hardy to withstand the relentless conditions of climate and soil. It is now believed that these most critical areas should never have been considered for cropping purposes.

But, once destroyed, to bring back a mantle of native grasses and its network of anchoring roots involves problems that are exceedingly difficult. Dry windy weather in the spring season frequently dooms the chances of a "catch." Even if one succeeds in obtaining a stand in the spring it may be damaged by heat and drought or injured and perhaps completely destroyed by grasshoppers. Many farmers have seen promising stands of grass destroyed by "hoppers," and this has led them to believe that hoppers are one of the most serious erosion-control problems.

Among the grasses that are adapted to certain areas in the northern Plains are crested wheatgrass (fig. 22), bromegrass, western wheatgrass, big and little bluestem, slender wheatgrass, blue grama, reed canary, needlegrass, switchgrass, side-oats grama, and others. Reed canary is limited only to wet and swampy places. Alfalfa and sweetclover are the adapted legumes.

Only three or four grass species are available commercially for regrassing purposes. These are crested wheatgrass, bromegrass, western wheatgrass, and slender wheatgrass. Western wheatgrass and crested wheatgrass are well-adapted throughout most of the region. Best results are usually obtained by

seeding a mixture of grasses rather than an individual species. Usually the mixture should contain a sod-forming grass and a legume. On seed plots, however, mixtures are to be avoided.

Bromegrass is best-adapted in the eastern part of the Dakotas and eastern Nebraska although it will compare favorably with crested wheatgrass in the western part of the region under favorable soil and moisture conditions. Slender wheatgrass is a short-lived grass but is useful in a mixture with other grasses in many parts of the region. The bluestems are most valuable in eastern Nebraska and in the sand-hill areas. Blue grama has a wide range of adaptation and is a valuable native species over most of the northern Plains.

FIGURE 22.—We cannot see the roots of this crested wheatgrass plant. If we could, they would be just as interesting as the portion above ground. This sample was photographed near Roundup, Mont., in June 1939. The wheatgrass was seeded in the fall of 1937 on abandoned but formerly cultivated land.

Crested wheatgrass has proved particularly valuable for use in revegetating abandoned croplands in many areas of the northern Great Plains. It is long lived, drought resistant, and winter hardy. Stands can usually be established with a high degree of certainty and at low cost by drilling directly into weed or stubble cover. Experimental grazing studies conducted in Montana and the Dakotas by the Bureau of Plant Industry and the State experimental stations show it to have a somewhat higher carrying capacity than native grasses. Its early growth makes it a valuable grass for almost any farm or ranch in providing pasture in the early spring before the native grasses have made sufficient growth to be grazed.

In most parts of the northern Plains seeding time is a critical period.

Experience has shown that there are three periods when the chances of success are the most probable. These periods are: (1) From August 15 to September 20 if there is plenty of moisture in the soil and if the area if fairly free of grasshoppers or other pests; (2) late in fall, preferably after November 1 in most parts of the region to insure no fall germination of seed; (3) in early spring before April 20.

In general, results indicate that late fall seeding holds the most promise for a successful stand.

On most fields, particularly if the area is exposed, crop residues from the previous crop should be left on the soil to collect snow and moisture and to serve as a mantle of protection for young plants after they emerge. Seeding in crop stubble or fields of Russian-thistle provides conditions which are somewhat similar to those found in nature. When the snow leaves, the temperature becomes suitable for growth, and the seed will have an opportunity to germinate and begin growth immediately. The young grass plants will then be in a position to compete successfully with weeds, which also begin their growth as soon as temperatures are favorable.

On the Plains the best results in seeding grass have been obtained by planting with a drill. In drought sections broadcasted seed may germinate, but successful stands are rarely obtained.

Generally speaking, 4 to 6 pounds of grass seed along with 2 to 3 pounds of legume seed is sufficient for an acre. The species of seed selected and the local soil and climatic conditions are among the factors determining the rate for a specific area. While depth of seeding is difficult to regulate, the best results are usually obtained when the seed is not covered deeply. Depth is more easily controlled if the seedbed is firm. Some farmers say it should be "firm enough to walk on the soil without sinking over the shoe soles."

Range Management

"I am on the executive committee of the association and president of the Dakota branch," Theodore Roosevelt wrote his sister in the East after he had attended the Stockmen's Convention in Miles City, Mont., in April 1884. He was running a ranch at the time on the Little Missouri, in Dakota Territory, now North Dakota.

At Miles City many cowmen from the north Plains gathered in a "jubilant and noisy" atmosphere to consider problems that affected the cattle industry. Roosevelt was elected to the executive committee as the successor of the colorful Marquis de Mores.

"The absorbing issues before the convention were the Texas fever and the overstocking of the range," wrote Herman Hagedorn in his Roosevelt in the Bad Lands.

> Industry depended upon cooperation. Each ranchman "claimed" a certain range, but no mark showed the boundaries of that range and no fence held the cattle and horses within it. On every "claim" the brands of 20 different herds might have been found. No ranchman by himself, or with the aid only of his own employees, would ever have been able to collect his widely scattered property. It was only by the cooperative effort known as the "round-up" that it was possible once or twice a year for every man to gather his own. The very persistence of the range as a feeding ground and the vitality and very life of the cattle depended upon the honest cooperation of the stockowners. If one man overstocked his range, it was not only his cattle which suffered, but in an equal measure the cattle of every other ranchman along the river * * *

The winter and spring of 1886–87 was disastrous for many stockmen. "I don't know how many thousand we owned at Elkhorn and Maltese Cross" (Roosevelt's ranches on the Little Missouri), said Merrifield, the manager. "But after that terrible winter there wasn't a cow left, only a few hundred sick-looking steers." Roosevelt returned in the autumn of 1887 and helped round up a trainload of cattle which he sold at Chicago at a loss. Prices had slammed down.

Then, as now, droughts and other climatic hazards along with overstocking, led to ruin. Then, as now, overstocking seemed to have reached its height at a time when the grass was least able to stand the punishment. Following several years of burning drought, livestock men were generally forced to reduce the number of animals on the range. Then came more generous rains. The grasses recovered and thickened. Livestock was increased to cash in on the better grass and the hope of higher meat prices. But inevitably when droughty years again returned, the range was again overstocked, and again stockmen were confronted with low prices.

Stockmen have, in the past, seen little inducement, individually, to preserve the public range. Individuals have understood in a general way the abuses of overstocking, but individuals could not combat a system based, in the main, on the old unwritten agreement, "first come, first served." A man might know from harsh experience that to overstock this year meant almost surely less pasturage in the years following. Yet, having no title to the pasture, he could not resist the temptation to take profit. He reasoned, and properly, that if his livestock did not get the grass, it would be grazed off by other men's stock. Even under private ownership, grasses on the range may suffer because of high overhead charges or depressed markets or for other reasons. But on public lands, without some measure of control by lease or permit, the individual stockman is even less able to adjust livestock numbers to grazing capacity.

Despite the deterioration of the grasslands since their occupation by white men, innumerable individual ranges are in as good condition as they were formerly, or in even better condition. The improved use of public lands received its greatest impetus when the Taylor Grazing Act was passed by the Congress in 1934. This act provided for a system of leases and permits which, among other requirements, is now helping to restore deteriorated ranges and to maintain those that are in good condition.

The list of range practices is long. Where applicable, these practices serve to restore the vigor and productiveness of the grass lands. In the main, these practices have emerged from the experience of successful stockmen, the agricultural colleges, the experiment stations, and the Forest Service over a period of years. The list includes: Stocking to grazing capacity, adopting a definite system of grazing, obtaining uniform distribution of livestock, grazing the class of stock that is best suited to the range, supplying and distributing adequate salt for livestock, and providing a sufficient supply of clean water. Above all, judge the results of management by the condition of the vegetation more than by the condition of the livestock coming off the range.

Experienced stockmen and skilled range examiners claim that proper stocking as to numbers is the key, by all odds, to an increase in forage production and erosion control (fig. 23). Without stocking in accordance with grazing capacity, they feel that alternative measures invariably result in further depletion and erosion, delay in restoration and, in the end, frustration of the aims of good management. For example: It is pointless to use mechanical devices such as contour furrows to coax the return of grass if additional hungry animals are allowed to feed off the new sheen of grass as soon as it emerges. And it is useless to provide additional watering facilities on a range if the grass has already been wounded by excessive numbers of livestock.

On the Plains a recent comparison of overgrazed and correctly grazed pastures

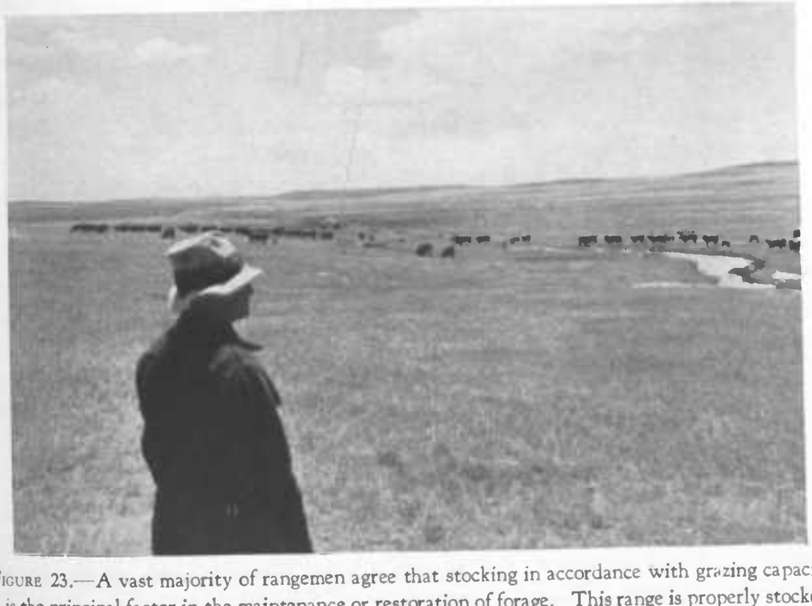

FIGURE 23.—A vast majority of rangemen agree that stocking in accordance with grazing capacity is the principal factor in the maintenance or restoration of forage. This range is properly stocked, and watering facilities make it unnecessary for livestock to trail an excessive distance.

of the same original climax type showed the density of vegetation on the overgrazed pasture to be one-third that on the properly grazed one. Because of unpalatable invading species of forage on the overgrazed pasture, it had but one-fourth the carrying capacity of the other.

Two neighboring pastures near Huron, S. Dak., will serve as another example. Both pastures are on similar soil with similar slopes. One has been properly grazed for at least 20 years, the other has been ovestocked. According to closely calculated estimates the overstocked pasture has but 0.4 the carrying capacity of the other. The reason is evident. The properly stocked pasture, on examination, showed that 98 percent of the forage consisted of blue grama, western wheatgrass, side-oats grama, and buffalo grass, all major perennials. These same major perennials accounted for but 40 percent of the forage on the overstocked pastures. Equally significant is the abundance of unpalatable plants found in the overstocked pasture and their almost total exclusion in the other.

When overstocking is a problem the range operator has a choice of at least three possible steps which may be taken to provide immediate improvement. He may secure additional range lands, he may sell excess animals, or he may provide additional supplemental feed to be used in a feed lot.

Often the disposal of surplus stock will solve the problem most easily. Stockmen on many of the soil conservation project areas have readily assented to the sale of as much as 25 percent of their livestock if such a reduction is warranted on the basis of carrying capacity of the range. This reduction of numbers does not necessarily mean that the operator will receive less income. For example, 225 head of improved stock might give the same net return as 300 head of inferior stock. Many herds need improvement through culling. Present information indicates that breed improvement and culling alone will make the stock on many ranges as much as 30 percent more profitable.

The replacement of nonproductive stock with fewer but better animals would largely correct present overstocking abuses.

A system of grazing generally applicable to the northern Great Plains is the deferred and rotation system. Under such a system one or more pasture units are protected from grazing until after seed maturity of the important grasses. The cured grass is grazed after seed maturity which permits the seed to be trampled into the soil. During the second year the same sequence is followed. In the third year other pasture units are protected from grazing until seed maturity (rotated for use during deferred period) and this system continues indefinitely. This system permits every pasture unit to have a complete rest during the growing season every three or four years. Studies of the results of these practices have demonstrated that on properly stocked ranges, increases of from 15 to 20 percent in forage growth may be expected, as compared with results on similar areas grazed yearlong.

Grass ranges are used to better advantage by horses and cattle, while browse is preferred by sheep and goats. Sheep and goats will thrive on grass ranges, of course, but they shun the coarser species and eat only the more tender shoots or seed heads. And cattle will graze many browse species, but they usually refrain until the better perennial grasses are eaten beyond the safety margin. Sheep are herded; cattle are not. For this reason sheep can be made to use rough, rocky ranges because their movements are continually guided by the herder.

Artificial aids may be employed to encourage animals to graze on the rougher parts of a range, or areas remote from water, and to prevent undue concentration

FIGURE 24.—This stock water pond, or dugout, in Wyoming catches water from a nearby highway and other nearby areas. The windmill in the background is used during exceptionally dry periods.

in other portions. Fences and salt are among the artificial means that may be used. Apart from the aid fences give in helping to distribute animals, they are sometimes necessary to shut out trespassing livestock, to enclose poisonous plant areas, and to obtain the advantages of deferred grazing. Fences on some cattle ranges may be unnecessary if salt is used properly and water facilities are adequately distributed.

"Salt is a cheap cowboy" is a saying born in the cattle country. Cattle graze from water to salt and from salt to water. Since salt attracts cattle it can be used as an economical aid in the control and distribution of animals over the range. With an eye for the protection of grass, most of the experienced rangemen place salt on areas less likely to be used, in order to obtain a more even use of the range. And they try not to place the salt within one-quarter of a mile of a

water supply. Of course the salt grounds are shifted from time to time to prevent damage to the range.

Among the numerous methods of distributing livestock over the range perhaps none is more important than the proper distribution of water. If watering places are sufficiently frequent over a range, excessive trailing is eliminated (fig. 24). Trailing not only checks the gain in weight of animals, but it also needlessly destroys vegetation. Climate, topography, soils, and vegetation must be considered in locating water supplies. Most rangemen feel that cattle and horses may travel 3 or 4 miles to water without much damage to the range, particularly if the country is flat to gently rolling. But if the country is rough or is occupied with heavy timber or brush, 1 to 2 miles or even less is preferable. Sheep should not be forced to travel more than 4 miles in winter or more than 1 mile in summer.

To date, the most appropriate application of contour pasture furrows seems to be in connection with, and complementary to, water-spreading systems. Surplus water that falls over spillways of dams or water from flash run-off originating on buttes or escarpments may frequently be deployed over comparatively flat areas for the benefit of grass.

Some Proving Grounds

THIS BULLETIN HAS sought to emphasize, over and over, that single measures of soil-saving strategy are inadequate. History sustains this view. George Washington tried to halt the march of gullies on his farm and failed. Thomas Jefferson experimented with horizontal plowing and failed. Later other Atlantic coastal farmers, and especially those to the South, tried terracing as a single measure of control. They too failed. It can be argued, of course, that Washington did not use the proper technique for gully control; that Jefferson's furrows were not on the true contour, and that the first terrace embankments were far too flimsy to do an effective job in holding water and soil. This is true, but even today with our more advanced knowledge and with the aid of high-powered equipment we are still retreating from the idea of using single measures to hold soil. Now as then, with but few isolated exceptions, it requires more than one method of control to make sufficient progress in checking accelerated erosion.

Since 1935 the Department of Agriculture has established numerous demonstration projects in scattered areas throughout the country. These areas vary in size from a few thousand to many thousand acres. Usually whole watersheds were selected. Each area was selected with the advice and approval of officials representing the experiment stations, the extension services, and the colleges of agriculture. Furthermore, each area was selected because the problems therein were typical of that particular part of the country.

From the beginning, it has been the fixed purpose of the Department of Agriculture that these areas should demonstrate a coordinated counter attack against erosion on the farm and range. With this central idea in mind it was necessary to employ every known device originating in the experience of farmers and governmental agencies, and to develop others in combination. In brief, these areas were designed to serve as testing and proving grounds where farmers and the public could view the use of control measures on a given field or farm.

A careful survey is made on those farms in which the owners have indicated their willingness to cooperate. In general, this survey reveals the extent of

erosion, the past and present use of the land, the slope of the fields, the tillage practices employed, the present vegetation, and the character of the soil.

With this information at hand, a complete program is developed for each farm or range unit. Each farm plan so developed differs in detail from every other unit plan in the area. Each plan was drawn to make effective use of modern soil and water-saving practices and at the same time to provide as large an income as is consistent with the long-time use of the land.

The following pages are devoted to a discussion of five different demonstration areas within the northern Plains region (see map on back cover). Space limitations will not permit the discussion of each of the demonstration areas. Neither will it be possible to discuss the work being done by C. C. C. boys in camps that are attached to several of the project demonstration areas.

Park River, N. Dak.

North Dakota's Park River project in Walsh County lies about 43 miles south of the Canadian border and 27 miles west of the Minnesota boundary. Ancient Lake Agassiz at one time covered much of this area, and the extinct glacial River Elk flowed through Elk Valley.

The project area contains 51,000 acres, and it forms the upper watershed for the South Branch of the Park River, which flows eastward to the Red. The elevation lifts from the eastern side from about 950 feet to about 1,400 feet at "the mountains," 10 miles to the west. West of "the mountains" the elevation drops at least 200 feet, forming the Elk Valley. But the elevation again rises to 1,400 feet, at the western edge of the project area, 5 miles beyond "the mountains."

Old Lake Agassiz once covered the lowlands with approximately 300 feet of water. The water, receding in successive stages, left definite bench marks or beach lines, which run approximately north and south and at right angles to Park River. The recently eroded river valley is narrow and quite deep in places, particularly so through the glacial-drift plains of the western portion and through the ridge of morainic drift hills on "the mountains" where it is bordered by escarpments and bluffs.

The variations in elevation and soil conditions, even within the limits of the project area, provide the basis for a mixed pattern of land use. On the level and exceedingly fertile soil of the eastern portion, the agriculture is typical of that found in the famous Red River Valley. Certified potatoes are the chief cash crop. Individual farms sometimes exceed 500 acres in extent. Spring wheat is another leading cash crop, while barley and flax are less important.

In the uplands the main cash crop is spring wheat. Potatoes, barley, and flax are also grown but they are of secondary importance. In this area the land is less valuable than it is to the east, and pasture occupies more of the farming land.

But over the area as a whole, pasture is very limited owing to the high percentage of land in cultivated crops. When the project was established in 1935, it was found that 73 percent of the land was in cultivated crops; 15 percent was in pasture; 6 percent was in hay land; and the rest was taken up by roads, woodland, farmsteads, and a few acres of wasteland (fig. 25). The same survey shows that cash crops provide 62 percent of the cash receipts, while livestock and livestock products, account for the remaining portion of the cash income. It is expensive to feed livestock through the long cold winter months. And since many farmers have succeeded in making a good living from cash crops there has been little inducement to change to what is now considered a better balanced system. The tenant situation can also be assigned as one of the reasons for intensive cultivation. Fifty-eight percent of the farm operators are tenants, and most of these operate on a 1-year lease. While many of these tenants stay more than 1 year on a particular farm, the 1-year leasing system is not conducive to livestock farming.

Despite the fact that snow and freezing weather usually protect the soil from 4 to 6 months each year, potatoes, like most other row crops, provide scant cover except for a short period during midsummer. Extreme cultivation, as elsewhere, has depleted the soil of much of the organic matter it contained when it was first plowed. Years ago many farmers burned their stubble fields. Some still burn strawstacks although the use of the combine has eliminated this practice on many farms. Fall plowing, until now, has been the rule rather than the exception. This practice served to reduce the rush of spring work, when farmers depended principally upon horsepower. Even though tractors are now generally

Figure 25.—Seventy-three percent of the land was devoted to cultivated crops when the project was established in the Park River area in 1935.

used, many farmers still plow in the fall of the year instead of in the spring.

Even a soil as productive as that in the Red River Valley shows the effect of the punishing practices mentioned above. When soil surveyors made an examination of the area when the project was established, they found that one-fourth of the topsoil had been removed from 57 percent of the land; that from one-fourth to three-fourths of the topsoil had been removed from 30 percent of the area; that three-fourths or more of the topsoil had been removed from 5 percent of the area. On 8 percent of the area there was no apparent erosion. All of these figures refer to wind erosion.

The most severe wind damage occurs on the bench or uplands to the west and not on the lower and more level lands to the east. Yet when the snow leaves in the spring there is some loss of soil from running water. But losses of water-borne soil are very small as compared with the soils that are moved by the wind after the melting snow has left fields without protection.

The sky has been darkened with black dust from these cultivated fields, particularly during such severe drought years as 1934 and 1936, yet the havoc in no way compares with the depleted ranges and crop damage to lands farther west in the northern Great Plains. Even so conservationists wryly refer to their "skyline" drive. On a bench west of Park River winds from the north in 1934 and 1936 piled soil 6 feet deep on an old roadway.

Control practices established on farms cooperating with the Service were determined in accordance with the needs of each individual farm. From farm to farm the practices vary considerably. Yet there are fundamental principles which are adhered to as strictly as practicable. For example, all cropland is strip-cropped, in connection with soil-conserving crop rotations, proper cultural practices, and the management of crop residues.

Since water erosion is of minimum importance as compared with wind erosion, contour strip cropping is not predominant. It is used, however, on those farms where the slopes range from 2 to 10 percent. All cultivated land with more than a 10-percent slope is either retired or in the process of being retired to perennial grasses and legume mixtures. Field windbreaks are being established on the west and north sides on most of the cultivated land that is susceptible to wind erosion (fig. 26).

Crop rotation has not been generally practiced by farmers in the project area. Each rotation is planned to give maximum vegetal protection without sacrificing sound cropping and cultural practices.

Although contour strip cropping is not widely recommended as yet on the project area, some form of strip cropping provides the basic foundation from which all farm plans are built. Crop rotations are worked into the strip-cropping pattern in such a way that each strip will be summer-fallowed or will produce a row crop once in 3 to 5 years. At the same time, other strips in the field will be devoted to small grain (wheat, oats, flax, barley). Some rotations may include

sweetclover. This is usually seeded in the wheat crop and cut for hay early in the succeeding year.

Much emphasis has been placed on the seeding of grasses and legumes to increase the forage for livestock, to retire badly eroded areas that are unfit for crop production and to provide a long-time grass rotation. The need for an increase of hay land to provide sufficient hay to carry livestock through the long winters and afford a surplus for drought years has long been recognized. But the use of grass in long-time rotations in connection with strip cropping is comparatively new. The idea is to seed a few strips on a farm to legumes or grasses (preferably a mixture of the two). These grasses or legumes (or the legume-grass mixture)

FIGURE 26.—Trees on field borders help to protect crops and soil against the wind.

remain on the strip from 5 to 7 years and in some instances longer. Since weather conditions and other factors are uncertain no one can tell how long it will take to establish satisfactory stands on these strips. For this reason one cannot set down on paper the precise time when a strip should be plowed up for cultivated crops. In practice most farmers feel that once they succeed in establishing grass or legumes on a strip, it should not be disturbed until they have succeeded in getting grass established on a new strip. This system, in time, will permit the use of grasses on each cultivated strip across the farm. Not only will these grass and legume strips provide hay for livestock and improve the soil, but they will also provide effective barriers against the wind.

Perhaps the most obvious and widespread control practice now to be seen on the Park River project area is the use of annual buffer strips in cultivated or fallow fields (fig. 27). In potato fields, for example, some farmers plant four to six rows of corn or sunflowers in strips about every 5 rods across the field (fig. 28). These stalks are left standing over the winter to provide a barrier against moving soil and to cause snow to pile up on the field (fig. 29). Other farmers, who nor-

FIGURE 27.—Wide row plantings of corn and other sturdy row crops are used to protect fallow soil against the wind.

FIGURE 28.—When the potatoes have been harvested, the corn strips protect the soil against the wind.

mally cut cornstalks for fodder, leave several rows of stalks standing in the field for the same reason. Still other farmers, rather than burn potato vines after harvest, disk them into the surface soil. The disk is run straight and in this way the vines are anchored in the soil rather than completely covered.

While the use of annual buffer strips is considered a big improvement over the practice of keeping an entire field in fallow, or the solid planting of cultivated crops like corn or potatoes, it is, nevertheless, only a compromise measure. Such a plan leaves out of consideration the beneficial effects of grass in the rotation. Some farmers feel that if they succeed in establishing grasses and legumes in strips across their fields there will be less need for the annual buffer strips.

Since many farmers have lost promising stands of grasses through drought and attacks by grasshoppers there is an increased interest in the use of sorghums. Twenty varieties of sorghum were planted in 1938 and again in 1939 to determine which are the best suited for this community. Height of growth, date of maturity, and the yield, both of forage and grain types, are among the principal factors that are being studied.

Field windbreaks of trees though somewhat less apparent than the strip-crop pattern of potatoes, corn, and small grains, are beginning to show their effectiveness for erosion control in the Park River area. If water erosion is the problem on a particular farm the trees are planted on the contour. Otherwise, they follow conventional boundary lines. In either case the trees are planted in belts from 5 to 10 rods wide and extend one-half mile or more. Tall, fast-growing trees are planted in the center, slower growing long-lived trees are next, and close-growing shrubs at the edges to check surface winds and to shade out grasses and weeds.

The few failures to get satisfactory stands in the tree belt can usually be attributed to inadequate preparation of the soil prior to planting or inadequate cultivation to keep down weeds after planting.

A considerable amount of native woodland still exists along riverbanks and stream courses. But like woods on most of the farms in the Middle West, it has been abused by overgrazing and improper cutting. When a cooperator has native woods in this condition, plans are made to exclude livestock so that normal reproduction will be possible. Some woodlands are in such bad condition that underplanting is necessary to place them in condition to check stream-bank cutting, provide cover for wildlife, or provide fence and building materials on a sustained basis.

One of the most prominent features of the pasture-improvement program in the project area has been the development and improvement of stock-watering facilities. And the dugout type of water hole has been found most satisfactory in this particular region. They are usually located in the center of pot holes or in creeks with low banks. A popular type is one excavated in the shape of a cross (fig. 30).

FIGURE 29.—Corn rows caught this drifting snow during the winter of 1938–39.

On those farms where stock water is a critical problem, perhaps no part of the program is more deeply appreciated. On one such farm the operator hauled water 4 miles from town in the fall of 1936. Daily for 3 weeks, it took a half day's time for man and team to supply enough water. "Nobody knows but us who have had to haul it, what it means * * * and how many barrels stock can drink," one farmer said.

Seventy-one farmers in the Park River area are cooperating with the Service in establishing improved practices on their farms. Table 1 gives some idea of the progress made in 5 years' time.

TABLE 1.—*Some improved practices adopted by 71 farmers on 17,276 acres*

Improved practice	Farmers using the practice specified—	
	In 1935	5 years later
	Number	*Number*
Plowing in the spring rather than in the fall	0	71
Using some form of strip cropping (windbreaks, shrub buffers, grass buffers, contour)	0	71
Using approved rotation of crops	0	71
Increasing grass and legume acreage	4	64
Planting rows of corn in fallow fields	0	8
Planting rows of corn in potato fields	0	35
Using seed source plots for grasses	0	8
Improving woodlands	0	22
Improving pastures	0	25
Using dugouts to provide water for stock	0	12
Planting field windbreaks	0	53

FIGURE 30.—A cross-shaped dugout dam, as shown above, is popular in the Park River area.

Froid, Mont.

Froid, Mont., is a few miles west of the North Dakota boundary and but one county removed from the Canadian line. A Service project, containing about 32,000 acres was established here in August 1936. Sheep Creek and Lost Creek are the principal drainageways. Both of these empty into the Big Muddy Creek, which flows into the Missouri near Culbertson.

Weather readings at nearby Culbertson from 1921 to 1936 show that the annual average rainfall for this period was a little under 12 inches. But farming would not be so hazardous if the rainfall was more uniform. In 1934 a little less than 5 inches of rain fell, and less than 9 inches fell in 1936. The extreme drought in 1934 was the worst on record, and that in the year 1936 was third in point of severity. In some years even though the total precipitation is very low, some of this may slash down in a few minutes. On June 23, 1920, 2.26 inches of rain fell in 80 minutes.

But the rainfall is hardly more erratic than other climatic features. Officially recorded temperatures vary from 49° below zero to 108° above. Even the wind does not blow steadily in or from a prevailing direction. Winds may come from any point on the compass, but observers believe that those from the northwest are probably the most devastating.

Blue grama grass predominates markedly on the native sod. There is some western wheatgrass, and some slender wheatgrass along with wiregrass and niggerwool. Shrubs, such as snowberry, wild rose, and buffaloberry, though not

plentiful, may be found. Trees are scarce. Some survive in deep ravines or coulees where they are protected from the wind and where they receive supplementary moisture through drainage and drifted snow.

Stockmen came into this country in the early eighties after the Indians were confined to reservations.

It was a good grazing country, but the livestock era was short. In 1906 the area was marked off in sections. A few settlers came in 1907, but the surge onto this sod almost amounted to a rush in 1908. By 1910 big steam outfits were tearing into the sod, and yields of 40 to 50 bushels of wheat per acre were not uncommon. Later, and particularly during and after the World War, gas-driven tractors turned under still more sod. By 1930 native pasture had been reduced to approximately 13 percent of the area whereas practically 100 percent was in grass at the turn of the century (fig. 31). While livestock numbers were cut down in about the same proportion that the wheat acreage was increased, most of the farmers carried a few head of stock.

By 1920 many farmers realized that straight wheat farming was undependable under the hazards of the region. Some started summer fallowing a portion of their land each year, and others tried oats. Still others tried alfalfa and sweetclover. On the whole these substitutes for straight wheat farming proved beneficial during the 1920's, but when severe drought appeared in the early 1930's even these measures failed. Since 1930 some farmers have grown corn and cane as a substitute for fallow. Barley and rye have been grown to a limited extent for pasture purposes. Most of the stands of alfalfa and sweetclover were killed during the recent drought years.

The predominant soils in this area are classified as Williams loam and Williams

FIGURE 31.—Straight wheat farming predominated in the Froid, Mont., area prior to 1920. Only 13 percent of the area was in native sod in 1930.

FIGURE 32.—These soils drifted severely when crops failed in the early 1930's.

fine sandy loam. They are productive soils under favorable moisture conditions. But, as elsewhere on the Plains, these soils have been punished severely by erosion even though they have been under cultivation a short time. By tilling the land each year for a wheat crop and burning stubble frequently to kill weeds, much of the organic matter had been destroyed. As a consequence these soils were in no condition to resist the wind when the crops failed in the early 1930's (fig. 32).

The task, when the project was established, was to striplist as much of the land as time and finances would permit. Both farmers and Service workers, however, realized that emergency listing was only an emergency measure to hold soil until other practices could be used. With practically all of the land under cultivation and with a rainfall that averages less than 12 inches, it was clearly apparent that less dependence must be placed on wheat even though rewarding crops could be harvested in some years. Adjusting the pattern of land use to the conditions at hand seemed to be the most significant problem to tackle. Briefly this meant a decrease in wheat acreage, an increase in the use of grasses, and an increase in the use of cultivated crops other than wheat. It meant also an increase in livestock as soon as an increased amount of feed could be produced. Along with this adjustment in land use, it was recognized that crops would have to be given every advantage possible through moisture-conserving measures.

The new rotations established on farms of cooperators provide that fallowed fields (or those growing corn or cane) will be followed by 2 years of grain. Under some conditions the plan calls for but 1 year of grain.

These new rotations are laid out in a strip-cropping pattern (fig. 33). Fallow strips of even width are so arranged that two strips of crops and three buffer

strips may be grown between them. In normal years the protective cover on the adjoining strips will prevent serious blowing and surface run-off.

If a particular field is fairly level—one with slopes up to 2 percent—the strips are laid in even bands across the field at approximately right angles to the prevailing winds. Contour strip crops are applied on fields that have slopes of from 2 to 6 percent, and the uneven areas between the strips are seeded to grass. As a general rule the fields that have slopes above 6 percent are retired from cultivation and seeded to grass.

The width of strips on this project area varies from 5 to 10 rods. On the more sandy soils the width is usually held to 5 rods, but strips of greater width predominate over most of the area.

On this project, as on most of the others in the United States, the cooperating farmers and Service workers have developed some unique ideas in the use of control measures. Most prominent here is the use of round ends on the crop strips.

Grass buffer strips are used between the contour strips to eliminate point rows. Usually a mixture of grasses and legumes is used rather than a straight seeding. The proportion used in most cases is 3 pounds of crested wheatgrass, 3 pounds of western wheatgrass, and 3 pounds of sweetclover per acre.

Shrub buffers are used on some fields as an additional protective measure. These shrubs, usually Caragana or Russian-olive, are planted in a single row about 18 inches apart on the median line of every other crop strip.

These bands of crop strips hugging the slopes on the contour present the greatest visual transformation on the project area since operations were started in 1936.

This valley looked especially promising in the early summer of 1938 since considerable rain had fallen in the spring. Some farmers counted on 40 bushels of wheat per acre, and the estimated average yield for the area was above 25 bushels. But rust appeared during the second week of July. On July 13 a horde of grasshoppers swarmed in from the Dakotas. Few fields were harvested. Some of those that were harvested produced only 2½ bushels per acre.

This was the first real chance for a crop since 1928. "We almost had a 40-bushel crop in our pocket when the 'hoppers' came," one farmer said.

But there was a bright spot in this otherwise drab picture. The excellent stands of grass and sweetclover sandwiched between the ruined wheat strips were estimated to yield at least a ton per acre. Many farmers immediately made plans to increase their livestock so that the feed could be used. This grass promised some income when hope was shattered for a cash crop of wheat (fig. 34).

Less apparent but not less significant is the progress that cooperators have made in improving their pastures. Control and improvement measures now

in use on pastures include: Rotational grazing, pasture furrowing, pasture terracing, stock-watering dams, and water-spreading structures.

Table 2 indicates the increased use of improved measures within the area in 3 years' time.

FIGURE 33.—A late seeding of wheat on the contour with alternate fallow and wind-buffer strips.

FIGURE 34.—A seeding of crested and western wheatgrasses which promises both feed for livestock and protection for the soil. Occasionally cash may be obtained through the sale of seed.

TABLE 2.—*A partial list of improved practices established on 19,960 acres of land in cooperation with 68 farmers within the project area*

Improved practice	1936		1939	
	Farms	Area	Farms	Area
	Number	*Acres*	*Number*	*Acres*
Contour cultivation	(1)	(1)	55	7, 146.7
Strip cropping	6	373	63	10, 213.4
Improved use of crop residue	(2) 20	(2) 3, 500	62	10, 004.1
Cropland retired to permanent pasture	(1)	(1)	36	1, 896.5
Cropland retired to permanent hay	(3)	(3)	52	3, 650.1
Regulated grazing on native sod	(2) 23	(2) 1, 000	47	1, 701.8
Regulated grazing on tame pasture	(2) 3	(2) 100	60	5, 437.2
Stock-water storage structures (capacity)	2	(3)	34	(4) 52.25
Flood-water diversions to prevent gullying	(1)	(1)	10	(5) 17, 168
Buffer plantings (shrubs planted)	(1)	(1)	34	(6) 389, 139
Gully structures	(1)	(1)	5	(6) 56

[1] None. [2] Estimated. [3] No data. [4] Acre-feet. [5] Linear feet. [6] Number.

Lander, Wyo.

High up in the Rocky Mountain foothills of west-central Wyoming lies the Shoshone Indian Reservation. The area is roughly rectangular in shape and contains about 2,338,600 acres.

About 1,438,633 acres in the reservation have been ceded to the United States Government by treaty or agreement. The remainder, about 800,000 acres, is commonly referred to as the diminished portion. Within the reservation there are about 70,000 acres under irrigation, and the remaining area is in grazing land, idle land, and woodland. Although 70,000 acres under irrigation is a sizable acreage it is small in comparison with the much larger body of land devoted principally to grazing.

Work on Big Horn Draw, 21 miles north of Lander, Wyo., carried on cooperatively by the Indian Service and the Soil Conservation Service, will serve as an example of control measures that are being developed on range lands in the reservation. Range land surrounding this draw covers about 35,000 acres. The draw is about 15 miles long and drops in elevation 1,200 feet between its source and its mouth, at Wind River, which borders the area on the south. The main drainage extends up the area for about 9 or 10 miles, where it branches into smaller drainageways.

For years this draw, which leads down to sparkling clear mountain water at Little Wind River, has been used as a livestock trail between winter and summer range. Indians and whites alike have used this pathway on a year-round basis.

The loitering herds on their way to water ate the turf closely, and their chiseling hoofs etched a network of trails throughout the whole terrain. But it was not the herds' leisurely traveling to and from water which caused all of the

damage. At least 350 head of nondescript ponies were milling over the area when project activities were started in 1936.

With frequent gentle rains and tolerant winds this land might have been able to withstand such punishment. But rains here, though few in number, are frequently torrential, and the wind occasionally moves soil, too. Gullies, many of them 6 feet in depth, with courses meandering down from the steep slopes into the center of the area, were prevalent in the draws. A channel, which in places was as much as 15 feet deep, was cut down the center of the draw. Sheet erosion was everywhere evident, for there was insufficient vegetation to check the speed of running water. The wind had blown off as much as a foot of soil in places. In other places soil had accumulated in hummocks 20 or more inches high.

The Indians were skeptical when they learned of the plans to check the charging waters in Big Horn Draw, but they said little. Some used their arms to

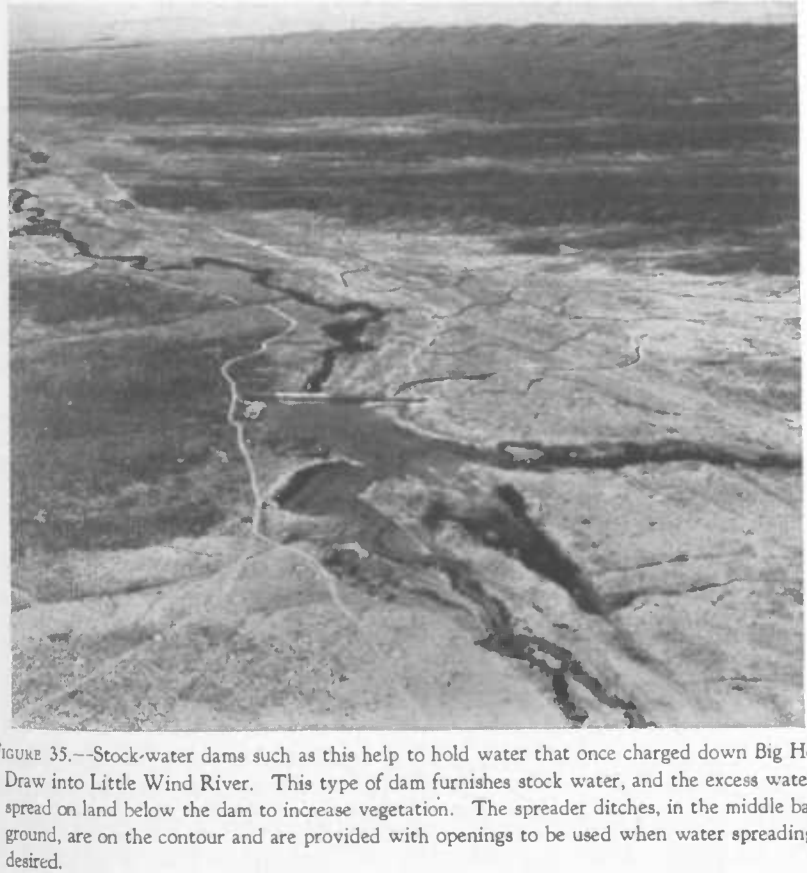

FIGURE 35.--Stock-water dams such as this help to hold water that once charged down Big Horn Draw into Little Wind River. This type of dam furnishes stock water, and the excess water is spread on land below the dam to increase vegetation. The spreader ditches, in the middle background, are on the contour and are provided with openings to be used when water spreading is desired.

show the white men how they had seen water roll and pitch after heavy downpours. The Service men were about ready to believe the Indians after a storm in 1936 washed out a newly established work camp near Wind River. When the work-camp facilities were reestablished the crew built a dam across the

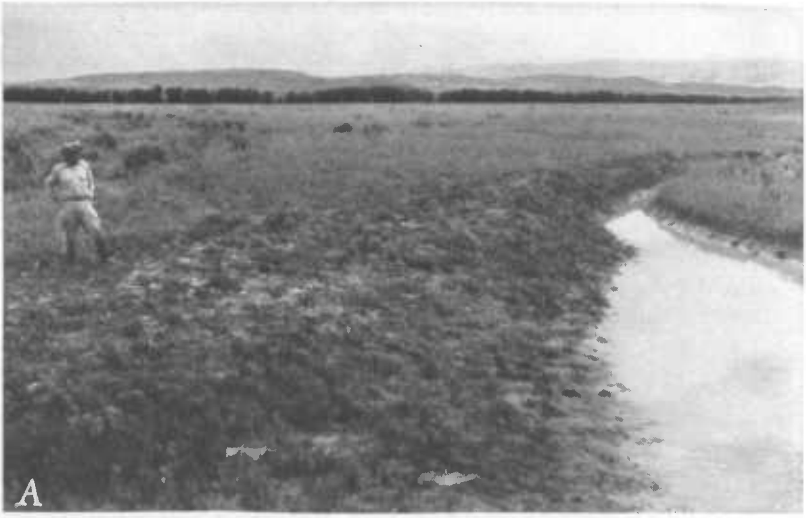

FIGURE 36.—A, This ranchman, at the left, is standing in an old water path that led to the main ditch in Big Horn Draw. The small diversion dike across this wash was built in 2 hours with a tractor and "tumblebug." Water that formerly went into the draw is now spread over 150 acres of good grassland; B, a continuation of the same spreader ditch. Note that the dike is on the downhill side to carry water from the diversion, and on the uphill side to spread the water.

lower end of the draw near the Wind River. Since the construction of the dam in 1936 until late in 1939 not a drop of water had gone over the spillway.

Rainfall was above the average in 1937, and torrential rains came in 1938 even though the total precipitation for that year was low. But the one dam built at the mouth of the draw, about which the Indians were so apprehensive, does not explain the absence of water and silt which normally went into Wind River. The Indians did not appreciate, at the time, how water would be held in check throughout the entire watershed.

Here is the story: In a sense both ends of the draw were worked against the middle. The main gullies were plugged with small dams and diversion ditches (made by a blade) which carried the water from the gullies onto the gentle alluvial bottoms where other spreading ditches kept the water deployed over the land and out of low places as far as possible.

Large stock-water dams were constructed approximately 3 miles apart to establish permanent watering places (fig. 35). Insofar as possible, the stock-water dams were located adjacent to fertile alluvial valleys where spillway water is carried out and spread to increase native forage production.

The spreading system was laid out to simulate an automatic system of irrigation. A ditch, made by the grader, was run off on a slight gradient and finally leveled on a zero grade. The ditch was broken for several feet on the high places to assure effective spreading. In places where the water would normally concentrate in depressions, additional ditches were made to carry it away. The purpose of the ditches is to hold part of the run-off and slow down and distribute the remainder of the water over a wide surface for maximum absorption (fig. 36).

But all of these structural developments would have been futile if improved grazing practices had not been put into effect. Trespass stock are kept from the area; sheep graze it during the winter, bed grounds are moved at least once every five nights, and the old, established bed grounds are avoided. A salting plan has been provided for both cattle and sheep. The salt is placed away from water holes and scattered out at strategic points.

After one season of water spreading, blue grama was clipped, on October 15, 1936, from plots 100 square feet in area, and its yield was compared to similar clippings of blue grama on unwatered areas, no plots being subjected to grazing. Two and eight-tenths times as much blue grama was produced on the treated area as on the untreated area. This is significant in that the grama constituted 96 percent and 89 percent of the total vegetation of the respective areas.

The following spring (June 21, 1937) similar clippings were made to determine the effect of increased plant vigor, resulting from the water spreading of the previous year, on the abundance of early spring growth. The amount of forage produced immediately below the water-spreading structures was two and one-tenth times as great as it was above. The differences on the treated area are

probably due to the impounding effect of the spreader ditch, which allowed the vegetation below the structure to receive both surface and underground water.

Southeast of Riverton, Wyo., is another range demonstration that includes 14,000 acres. Wind River, which lies to the north, was the only permanent source of water for livestock in this area prior to the development of facilities when the demonstration was established. As in Big Horn Draw, livestock had trailed back and forth across this range to water for perhaps 40 years. Trailing and overuse had so reduced the vegetation that much of the land provided scant feed or cover.

When range examiners mapped the area in 1935 they found that many of the more desirable grasses were depleted and lacking in vigor. By 1938, after control measures had been established, these grasses were showing improvement both in stand and in vigor. In the main the control measures used follow the pattern of those effective on Big Horn Draw. In both areas the response of grass in 3 years' time has caught the attention of stockmen, some of whom have driven as much as 400 miles to see the demonstrations (fig. 37).

Farmers on the irrigated lands adjacent to Wind River, in the Riverton area, have erosion problems which are different but no less intensive than the problems of those who make their living entirely from grazing lands. The work carried on in Fuller Draw and the adjacent irrigated lands, 10 miles to the northeast of Riverton, will serve as an example.

The draw itself is about 3 miles long and one-half to three-quarters of a mile wide. Surrounding the draw is a horseshoelike mesa about one-half mile wide which is a part of the drainage. From the edge of the mesa the drainage breaks into rough broken terrain with slopes of as much as 50 percent on either side of the draw. Many slopes are barren. Others have only a sparse cover of sagebrush, western wheatgrass, grama grass, sedge, and needlegrass.

Most of the time this watercourse is dry and harmless. There are few rains, but the few that come are usually torrential, and flash run-off is the rule rather than the exception. For 25 years these periodic floods caused damage. Crops were ruined, irrigation canals were filled with silt, highways, and railroads were washed out, and gullies were cut in fields worth $50 or more per acre.

The 15 farmers who have land at the foot of the draw could not hope to solve the problem individually. Clearly it was a problem for the ditch companies, the county and State highway officials, the Indian Service, and the Soil Conservation Service in addition to the farmers.

A complete program of control for the draw was agreed upon by the governmental agencies concerned and by a committee representing the farmers. First of all a range-management plan was agreed upon. Grazing is limited to the period between October 1 and April 15. This allows a complete growing season for the benefit of vegetation. On the flat-topped mesa approximately 20 miles of water-spreading furrows were constructed. In the main draw the work crew

built five earth-fill dams at strategic points, and all were provided with a vegetated spillway. The fifth and last dam in the draw, counting from the top down, is provided with an outlet pipe. If water rises to this outlet it may be diverted into the irrigation canal to augment the supply for use on the land. Otherwise, all of the water will remain behind the earth structures, both large and small, throughout the watershed.

Two severe cloudbursts occurred during the spring and summer of 1938. All of the dams had water in them after these storms, but no water escaped, and of course there was no damage.

FIGURE 37.—Stockmen, some of whom drove 400 miles for this observation tour, are noting the response of grass to water-conserving measures.

Bringing the water in Fuller Draw under control was unquestionably the first problem that needed solution. But crop farmers below the draw realized that they had other erosion problems. Beans and sugar beets had been grown for years. Yearly cultivation had made much of the soil vulnerable to the action of wind. Occasionally so much sand would move with the wind that it was impossible to get beets to grow, and irrigation ditches were frequently clogged by the wind-driven soil. The unwise, and sometimes careless, use of irrigation water was still another factor that caused damage to the soil.

The cooperating farmers are adopting improved tillage and rotation practices. They are also improving their methods of distributing irrigation water. The improved crop rotations usually call for 1 year of grain, 2 to 3 years of alfalfa, and 3 years of row crops. Some farmers are using winter rye to turn under in the spring for green manure; others are using sweetclover for the same purpose.

Plum Creek, Nebr.

A soil and water conservation project was established on a fingerlike strip of land in Boone and Nance Counties, Nebr., in the spring of 1934. Water falling on this land drains into Plum Creek, which has its source near the lower limits of the Sand Hill region. Thirty-two miles to the southeast, Plum Creek waters enter the Loop River. Farmers living near Plum Creek, and particularly when they are in an extravagant mood, claim that the stream is so named because it runs either "plumb" full or "plumb" dry.

This area includes about 70,000 acres, and it lies at the approximate divide between the Corn Belt to the east and the Plains to the west. Mammoth corncribs, farm elevators, feeding sheds, and hog houses are more suggestive of Corn Belt agriculture than of the wheat and cattle farms to the west. Yet in recent years, and since drought has made an indelible impression on the whole of this area, many citizens are wondering if they too are not living near the lip of the so-called Dust Bowl. "This was a great country up until about 10 years ago" many of the folks will now tell you. Grasshoppers, drought, and low prices seem to have combined their attacks to make conditions serious.

Loessial soils predominate in the area. The bumper crops grown here in good years during the 1920's and earlier gave ample evidence as to the productivity of the soil. Boone County at one time was among the banner corn-producing

FIGURE 38.—Over 80 percent of the land in the project area was broken for cultivation in 1934. Up-and-down-hill cultivation is one of the causes of severe soil and water loss.

areas of Nebraska. "Deep, very fertile, and productive," are words used by early surveyors in describing the region. It has a friable, mellow topsoil, and on its virgin soils organic matter was 2 feet deep or more in some locations.

But this good soil invited intensive cultivation. When soil surveyors mapped the area in 1935 they found 82 percent of all the land broken for cultivation and only 18 percent of the area in pastures, meadows, and wasteland. Sixty percent of the cultivated land was in row crops, 29 percent was in small grain, and 11 percent was in alfalfa (fig. 38).

Unquestionably soil troubles would not have developed so quickly in this area if the slopes were more gentle. Slopes vary from about 5 percent on the uplands to 20 percent or more on the "cat step" banks nearer the stream. But slopes are not the sole cause of the trouble. The soil, though rich and comparatively absorptive, is usually underlain with a slightly heavier subsoil. This feature, combined with the intensive use of the land that left much of it open to the weather, along with hazardous slopes, is the reason back of the extensive losses of soil and water.

Losses of soil of course can only be estimated. The original topsoil of 10 to 12 inches is now reduced on much of the sloping land until only 4 or 5 inches remain. In some cases all of the topsoil is gone, and the subsoil is being cultivated.

As a result of soil and water wastage the yields on many fields have declined, and gullies have become more and more troublesome (fig. 39).

FIGURE 39.—This gully in rich Boone County soil is 7 years old. Run-off water following a wagon track cut a gash in the land 8 feet deep and 10 to 12 feet wide.

Most farmers wanted to do something to control the gullies that were rapidly marching up the slopes on the better cultivated land. Gully-control structures such as brush and earth dams and the planting of trees were seized as an opportunity to check the formation of gullies and at the same time make the field safe for the production of corn, the chief cash crop.

Gully-healing structures, therefore, were the most obvious control measures that appealed to farmers at the time. It took time and patient persuasion to convince some farmers that gullies could not be controlled without additional erosion-control practices such as terraces and contour farming.

The problem of convincing land operators that not one but many practices are needed on most damaged fields was made more difficult since 72 percent of the farms in the area were run by tenants. Moreover the large majority of the leases with the landlord were drawn for 1 year, and the annual turn-over among tenants has been about 25 percent in recent years.

The recommended cropping system is designed to bring a greater percentage of the land under such crops as grass-legume mixtures, and the small grains such as oats and barley (fig. 40). Wheat is not considered a well-adapted crop for this region, and for that reason it has a minor role in the rotation of crops.

The conservationists reasoned that corn must continue as the major crop in any improved-cropping system. One of the common rotations worked out with cooperating farmers provided for corn 3 years, oats and clover the fourth year, and clover pasture the fifth year. Even better, another rotation provided for corn only 2 years in succession. Still other rotations included 1 year of corn, 1 year of oats, with sweetclover planted in the oats, and the full third year in sweetclover to be used for pasture.

Alfalfa was at one time grown extensively in the project area. But this deep-rooted crop eventually consumed the available moisture in the subsoil. Since rains have been insufficient to replenish this soil moisture, alfalfa has failed in most instances.

Some success has been obtained in seeding bromegrass in rows with a deep furrow drill. But as yet too little is known about the length of time it will take grass to cover the land between the rows to recommend the practice widely.

Where terraces have been given the support of good cropping systems and where the channels have been kept clean they have done their part to save soil and water. Most of the early terraces were built level, with the idea that they could retain all of the water on the field. With experience to guide them, most engineers now feel that terraces should be given a slight fall under most conditions.

Despite adverse weather and grasshopper attacks, which cause the failure of many grass stands, and the difficulty of establishing crop rotations on a systematic and permanent basis, considerable progress has been made. At the end of a 5-year period, approved crop rotations were in use on 25,440 acres; residue

Figure 40. Corn and small grain in strips help to hold soil and water on this Nebraska field.

management was being practiced on 8,000 acres; proper tillage practices were in use on 26,733 acres; 10,567 acres were being farmed on the contour; controlled grazing was being practiced on 4,012 acres, and 60 acres had been planted to trees.

The work accomplished in the area during the 5-year period is also responsible in a large measure for the organization of three soil conservation districts. The Plum Beaver District, comprising 100,000 acres, embodies the greater part of the project area. The other two districts are in adjoining counties.

Huron, S. Dak.

Two separate areas of land are included within the first conservation project established in South Dakota. The major portion of the project lies within Beadle County in the east-central part of the State. The larger of the two areas consists of 144,000 acres which form the watershed for Shue Creek. The smaller area of 46,000 acres lies in the Wolsey district, 8 miles to the west of the larger area.

Much of the land in these areas is gently rolling, and the undulations are most pronounced near stream channels. There are some spots of rather flat tableland, but these are small and are usually remote from the streams. The greater part of the water runs into depressions causing numerous small ponds, which eventually disappear through percolation and evaporation.

Soils of Beadle County are developed on material that is of glacial origin. Some have been formed on the unstratified drift and some on material that has been

transported and redeposited as glacial terrace or as recent alluvium. The soil material is derived from granite, limestone, sandstone, and shale rocks, and the drift varies in thickness from a few feet to over 100 feet. The Barnes soils are the most extensive, forming about 65 percent of the area in the county.

The peak of settlement in Beadle County was reached shortly after 1880. Within 2 or 3 years after that date practically all of the desirable land was filed upon. Wheat was grown almost exclusively. The first crops were bountiful for rains were above normal from 1880 to 1893. But in 1894 and 1895 little rain fell, and wheat was almost a total failure.

During the period of high yields many farmers mortgaged their farms to expand operations and purchase equipment. But much of this expansion could not be financed during the lean years, and a large number of farms were foreclosed. This was the first real setback the farmers experienced. Some, it is true, had given attention to stock raising along with the production of crops other than wheat. But, in general, large wheat farms were made even larger.

Between 1895 and the outbreak of the World War, agriculture flourished in the good years. There was a distinct retreat from straight wheat farming. The trend was toward the rotation of crops and the use of other measures that are suggestive of a more permanent type of agriculture. But during and immediately after the World War wheat acreage again expanded. The cultivated acreage of the area was vastly increased, and much of the progress made earlier toward a better balanced system of farming was lost.

FIGURE 41.—This highway snow fence served as a soil fence in December 1935. The loose, dry soil fell freely from the man's hands.

The continuous production of wheat, as elsewhere on the Plains, led to a depletion of organic matter in the soil. A soil analysis made by the State Soil Survey in 1919 showed that the cultivated soils of 10 important soil types contained, on an average, 20 percent less organic matter than the virgin grasslands of the same types.

During the past few years crop yields have dwindled because of scant rainfall. A feed scarcity developed, and stubblefields and pastures were heavily overgrazed. The crop residues were consumed, leaving the dry, loose topsoil exposed to the ravages of the wind (fig. 41). Fall plowing and summer fallowing further aggravated the condition by leaving the soil exposed during the winter.

When project operations were started in the middle 1930's, it was not unusual to see fields stripped as though by a sandblast to a depth of 4 to 8 inches, depending upon the plow depths. But on some of the more sandy areas soil was blown out much deeper than the plow line. Fields once fairly level were covered by hummocks and basins, making cultivation difficult or impossible without drastic and expensive mechanical treatment. Fence rows were filled to depths of from 3 to 6 feet, and widths from 2 to 6 rods with rich black soil or sand. In sand-dune fashion this material moved back and forth with each change of the wind.

A reconnaissance survey, made when the project was first established, revealed difference in the degree of erosion in the two areas. In the Shue Creek area 45 percent of the acreage showed serious damage, while at least 65 percent of the land in the Wolsey area was in a similar condition.

The control problem which faced farmers and soil conservation workers in the Huron area after the severe blows in the early 1930's was twofold. The most pressing and immediate problem was to clear soil and sand from doorways, farm yards, fence rows, and roadways as well as to level the hummocky fields in preparation for crops (fig. 42). A far greater problem was to develop a long-time system of agriculture and agricultural practices that would ameliorate or prevent the recurrence of the disaster.

Control measures, in the main, are the same as those heretofore described in other demonstration areas. There is a difference, however, in the emphasis placed upon certain features. For example, effort has been made to return a larger proportion of the land to grass than in some of the other demonstation areas of the northern Plains. This one measure in itself involved profound changes, since the customary system of farming had to be entirely reorganized to provide for livestock rather than cash-grain crops solely. With adverse climatic conditions to contend with, it has been no easy matter to establish grass and legumes or to hold the soil until such crops could get a start.

The experience of both farmers and technicians leads to the conclusion that early-fall seeding of grass is preferable to either late-fall or early-spring seeding. In a particular year, however, much depends upon the moisture conditions or the extent of grasshopper infestation. Late-fall seedings have been fairly successful

though less so than those in September. Early-spring seedings as well as some of the November seedings suffered severely from moisture deficiency and soil crusting in April. On severely eroded land with small sand hummocks and

FIGURE 42.—A, Despite emergency listing, the wind punished this field in 1936; B, in 1937 the same field grew a crop of cane and Sudan grass.

where the vegetative residue was scant, progress has been made by alternating four rows of rye and two rows of grass. This is accomplished by partitioning off the drill holes. Excellent results were obtained by this method, particularly where packer wheels were used to firm the soil and prevent deep seeding.

On land where sand had drifted into large hummocks, experience has proved that more extreme measures are necessary to prepare the soil properly for seeding. The lister was frequently used on the areas surrounding these hummocks. The lister furrows provided traps to catch sand that was later blown from the dunelike hummocks. Cane and Sudan grass were later planted in the furrows

FIGURE 43.—Most of the improved crop rotations provide for the use of grass in a strip-cropping pattern.

if sufficient moisture was obtained to warrant the trial. Such areas, where a vegetative residue had been restored, were seeded to grass.

Crop rotations on cultivated land operated by cooperating farmers are determined principally by the condition and character of the soil (fig. 43). On the sandier soils the program calls for the inclusion of one-half corn and one-half of small grain for not more than 10 or 12 years, provided a soil-building crop such as sweetclover is grown with the small grain at least twice during the period. Following this period, a grass and legume mixture occupies the land for 6 to 8 years, after which grain crops may again be grown.

On loamy soils the plans usually provide for one-third corn or cane and two-thirds small grain for 10 to 12 years. Following this a grass-legume mixture occupies the land for 6 or 8 years.

There are other variations in crop rotations. In general the plans provide for permanent grass and legume crops on the soils that are particularly subject to erosion. And the plans provide for the use of legumes and grasses on soils less subject to erosion to rebuild soil structure and restore fertility.

In the improvement of pastures in the area the chief emphasis has been placed on proper management. This includes restricted grazing, deferred grazing, rotation grazing, and the use of supplementary pastures of Sudan grass along with the distribution and development of watering facilities. It is now believed that fully 90 percent or more of the overused pastures can be restored through the application of these measures.

As a result of improvements in the technique of planting trees and improved cultivation, where there has been a fair break with the weather the survival of windbreak plantings has risen perceptibly. In 1938 the cultivated windbreaks showed an average survival of 86 percent. Likewise improvements made in establishing dam and reservoir plantings are notable. Trees and shrubs are now planted in subsoil furrows on the contour, and the average survival of such plantings in 1938 was 75 percent.

In making these plantings, the needs of wildlife have been kept in mind. Trees and shrubs, along with the increased vegetation on cropland have provided food and cover, and wildlife numbers have shown a hearty response. The Osmanson Reservoir is an outstanding example (fig. 44). From an unsightly mudhole surrounded by eroded fields this site has been converted into a verit-

FIGURE 44.—A bird's-eye view of the Osmanson Reservoir, in Beadle County, S. Dak. A wildlife tally in 1938 showed 325 ring-necked pheasants, 50 Hungarian partridges, 20 prairie chickens, 500 ducks of several species, 150 mud hens, 5 bitterns, 300 red-winged blackbirds, 150 or more yellow-headed blackbirds, 15 black-crowned night herons, 6 great blue herons, and 6 colonies of muskrats.

able wildlife haven. In a census estimate taken during the fall of 1938 the following number of birds and animals were recorded: 325 ring-necked pheasants, 50 Hungarian partridges, 20 prairies chickens, 500 ducks of several species, 150 mud hens, 5 bitterns, 300 red-winged blackbirds, 150 or more yellow-headed blackbirds, 15 black-crowned night herons, 6 great blue herons, and 6 colonies of muskrats

By midsummer in 1939, 232 farmers in the two areas were cooperating with the Service in putting into effect land use and control practices on their farms. The total area under agreement was a little over 60,000 acres. On these 60,000 acres 37,627 acres were under some form of strip cropping, 27,296 acres were under residue management, 10,443 acres were under improved tillage practices, 3,457 acres were seeded to grass and legumes for soil-building purposes, 12,529 acres of pasture land were under controlled grazing, and 1,512 acres were planted to trees in woodland plantings.

Spreading Control by Community Action

WIND AND RAIN respect no man-made boundary lines. This is sufficiently obvious to require no elaboration here. It is the reason, however, for the necessity of finding means to spread the benefits of proper land use and control measures beyond individual farms or ranges. As promising as the controls and cures may appear on the treated farms or indeed on the isolated and scattered project areas, they are inadequate to deal with the problem as a whole.

The Department of Agriculture realizes that while demonstrations can indicate the way, means must be found to bring about more appropriate land use and control measures on the much larger bodies of land that surround the treated spots and areas.

As a step toward the solution of this problem the Department, in 1936, suggested that States pass in their legislatures enabling acts establishing soil conservation districts for erosion control. By August 1939, 36 State legislatures had passed legislation which was, in essential features, based upon the objectives sought in the standard act proposed by the Department. Four of the five States that make up the northern Plains area have such legislation.

This enabling legislation provides a mechanism whereby people may, through democratic procedure and action, bring about the desirable changes, which individuals alone could not accomplish (fig. 45).

Assuming that an enabling act has been passed in your State and assuming minor variations under the laws of the respective States, this is how the districts are formed and how they operate:

You are a farmer. You and your neighbors desire to organize for the purpose of pursuing a cooperative erosion-control program.

You petition the State soil conservation committee, asking it to organize a district and to include your land within its boundaries. This petition must bear the signatures of a certain number of land occupiers or landowners. This number varies in different States.

After your petition is presented, the State committee holds a public hearing and, guided by the testimony given at the hearing, decides whether a district is needed. If a district is needed, the committee defines the boundaries of the district and gives notice of a referendum. The district may include all or parts of several counties; or, if the problem is localized, the district may be smaller than a single county.

All land occupiers or landowners may vote in the referendum, according to the procedure and conditions laid down in the State law. If a majority vote against creating a district, that ends it. If a large majority vote in favor, the State committee appoints two supervisors. The appointed supervisors file an application for a certificate of organization with their secretary of State. When the

FIGURE 45.—Soil conservation districts provide a legal mechanism through which landowners may voluntarily provide for improved land use measures.

certificate is issued, the district comes into being, and an election is held to elect three more supervisors.

The board of five supervisors then studies the problems of the district and formulates a program of erosion-control projects and decides on preventive measures. The committee may call upon the personnel of State and Federal agencies for help with this work.

The supervisors then proceed to carry the program into effect, securing such technical assistance and buying such equipment as their funds permit and the program requires.

Let us say that the community and its supervisors have tried to induce the minority to cooperate and put soil conservation measures into effect, but they have failed. What now? The supervisors turn to their second set of powers, which permits them, as elected representatives of the people of the district, to

draw up soil conservation ordinances and submit them to a vote of the people. You vote "yes" or "no." If the vote is against regulations, that ends, or halts, the whole new procedure. But let us say that the vote is close, with a small majority in favor of regulations. If your State law requires only a majority vote, the supervisors may or may not invoke the proposed regulations. They probably will not. But let us say that a large majority favored the regulations. Then, doubtless, your supervisors will declare them in force. Should the hold-outs still refuse to employ the conservation measures called for by the regulations, your supervisors may petition the local court to order the land occupier to observe the soil conservation ordinances. The court order, if issued, may provide that if a land occupier fails to employ the conservation measures the regulations require, your supervisors may go on his lands, do the necessary work, and collect the costs from the land occupier; or, in a few States, the court could fine him for committing a misdemeanor.

The laws require that a board of adjustment be established in districts which adopt land use regulations. This board is authorized to permit exceptions and variances from land use regulations in cases where the application of the strict letter of the law would result in "great practical difficulties or unnecessary hardship." The decisions of the board of adjustment are, of course, subject to review in the local courts.

It is possible that there will be districts in which the procedures just outlined will prove impractical. The laws therefore provide that after a district has existed for a certain number of years (5 years in most of the State laws), farmers may petition to have the district dissolved. The question of dissolution is then submitted to a referendum. If a sufficient number of the people affected vote to dissolve the district, it is done.

By December 1939, 18 districts, including 4,807,425 acres, had been organized and were at work in the northern Plains; 6 districts, including 526,083 acres, had been organized but no work started; and 8 districts including 2,348,960 acres, were in the process of organization.

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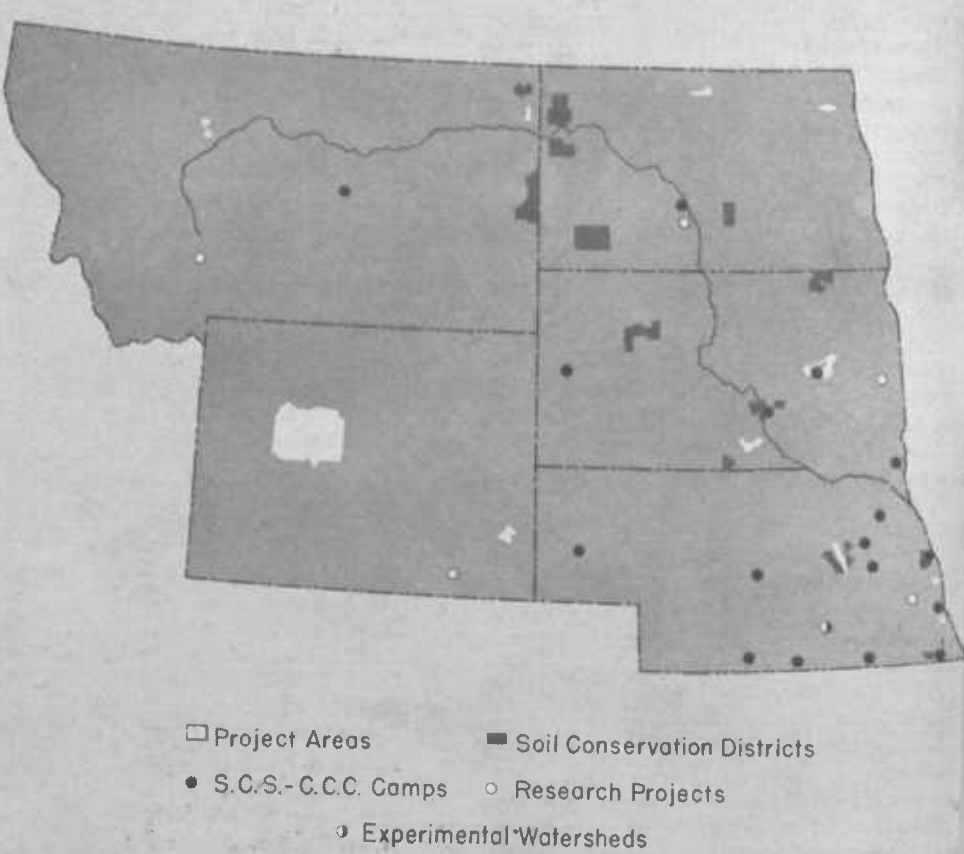
Project Areas
Soil Conservation Districts
S.C.S.-C.C.C. Camps
Research Projects
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